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<b>(54) Title:</b> PHARMACEUTICAL COMPOSITIONS COMPRISING A SOLUBLE LAMININ RECEPTOR PRECURSOR OR A COMPOUND WHICH BLOCKS THE INTERACTION OF THE LAMININ RECEPTOR PRECURSOR AND PrP <sup>Sc</sup> OR PrP <sup>C</sup>		
<b>(57) Abstract</b> <p>The present invention relates to pharmaceutical compositions comprising a soluble laminin receptor precursor (LRP) or a modification thereof. The present invention also relates to pharmaceutical compositions comprising a compound which blocks the interaction of LRP and PrP<sup>Sc</sup> or PrP<sup>C</sup>. Said compositions allow the treatment of diseases associated with the presence of PrP<sup>Sc</sup>. In addition, the present invention provides an expression vector for the recombinant production of LRP or any other kind of protein in the baculovirus system.</p>		

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**PHARMACEUTICAL COMPOSITIONS COMPRISING A SOLUBLE LAMININ RECEPTOR PRECURSOR OR A COMPOUND WHICH BLOCKS THE INTERACTION OF THE LAMININ RECEPTOR PRECURSOR AND PrP<sup>Sc</sup> or PrP<sup>C</sup>**

The present invention relates to pharmaceutical compositions comprising a soluble laminin receptor precursor (LRP) or a modification thereof. The present invention also relates to pharmaceutical compositions comprising a compound which blocks the interaction of LRP and PrP<sup>Sc</sup> or PrP<sup>C</sup>. Said compositions allow the treatment of diseases associated with the presence of PrP<sup>Sc</sup>. In addition, the present invention provides an expression vector for the recombinant production of LRP or any kind of protein in the baculovirus system.

Prion proteins are thought to play a central role in the pathogenesis of transmissible spongiform encephalopathies, such as bovine spongiform encephalopathy (BSE), Creutzfeldt-Jakob disease (CJD) and Scrapie (Prusiner, 1991). This unique group of neurodegenerative disorders can be inherited due to known mutations in the chromosomal prion protein gene, they can originate sporadically and can be caused by transmission of infectious particles prepared from organs of affected organisms (for review see Weissmann et al., 1994). The transmissible agent seems to be an infectious protein (PrP<sup>Sc</sup>) capable of replicating in the host in the absence of any nucleic acid (Prusiner et al., 1982; Alper et al., 1967; Griffith 1967), although recent transmission studies of the BSE agent to mice suggest that PrP<sup>Sc</sup> might be involved in species adaptation, but that an unidentified agent may actually transmit BSE (Lasmezas et al., 1997). PrP<sup>Sc</sup>, a pathogenic isoform of the normal host-encoded PrP<sup>C</sup>, is thought to convert host-PrP<sup>C</sup> into PrP<sup>Sc</sup> resulting in pathological modifications in the brain such as spongiform vacuolation, astrocytic proliferation and neuronal loss.

PrP<sup>C</sup> and PrP<sup>Sc</sup> are identical regarding primary structure (Stahl et al., 1993), but CD- and FTIR-spectroscopy reveals that they have different secondary structures (Meyer et al., 1986; Pan et al., 1993). PrP<sup>C</sup> has a very low content and PrP<sup>Sc</sup> a high content of  $\beta$ -sheet structure. Moreover, PrP<sup>C</sup> can be hydrolyzed completely by proteinase K, whereas PrP<sup>Sc</sup> is degraded to the proteinase K resistant infectious core PrP<sup>27-30</sup>

(Caughey *et al.*, 1991; Prusiner *et al.*, 1981; 1983; 1984). A proteinase K sensitive, soluble and presumably non-infectious version of PrP<sup>27-30</sup>, designated as sPrP<sup>27-30</sup> was identified in human platelets (Perini *et al.*, 1996) and might also act as a precursor for proteinase K resistant PrP<sup>27-30</sup>.

The conversion of PrP<sup>c</sup> into PrP<sup>Sc</sup> is thought to involve structural rearrangements of the polypeptide from  $\alpha$ -helix to  $\beta$ -sheet. Two models are currently used to describe this conversion mechanism. According to the heterodimer model (Prusiner, 1982) one exogenous PrP<sup>Sc</sup> molecule contacts host PrP<sup>c</sup> resulting in a PrP<sup>c</sup>-PrP<sup>Sc</sup> heterodimer which refolds into a PrP<sup>Sc</sup>-homodimer. In contrast, the nucleation dependent polymerization model (Lansbury and Caughey, 1995) proposes that infectivity is a property of a PrP<sup>Sc</sup> oligomer, which can act as a seed for polymerization.

The physiological role of the cellular prion protein PrP<sup>c</sup> was investigated with a series of knock-out experiments leading to controversial results. Most of the researchers did not recognize any changes in the behaviour or reproduction of PrP-knock-out mice (Bühler *et al.*, 1992). More recent investigations with PrP<sup>0/0</sup> mice suggested an important role of PrP<sup>c</sup> in synaptic function including an efficient GABA<sub>A</sub> receptor-mediated fast inhibition (Collinge *et al.*, 1996) whereas another study did not find any dysfunctions of synapses in the hippocampus (Lledo *et al.*, 1996). These discrepancies in the observation of phenotypes in PrP<sup>0/0</sup> mouse lines may be due to the genetically heterogeneous background (Borchelt and Sisodia, 1996) and the different age of the animals. In summary, the physiological role of PrP<sup>c</sup> remains unclear. However, PrP<sup>0/0</sup> mice lacking the *prn-p* gene are, in contrast to wild-type mice, resistant to infections with the mouse PrP<sup>Sc</sup> (Bühler *et al.*, 1993) demonstrating that PrP<sup>Sc</sup> is essential for the development of Scrapie and Scrapie-like disease. More recent experiments demonstrated that PrP<sup>c</sup> is necessary for scrapie induced neurotoxicity (Brandner *et al.*, 1996) and required for scrapie spread within the central nervous system (Brandner *et al.*, 1996b).

So far, a receptor or coreceptors for prion-protein, which might be involved in the proliferation of PrP<sup>Sc</sup> could not be identified. In addition, no method exists for the treatment of the above cited diseases which are related to the presence of PrP<sup>Sc</sup>.

Thus, the technical problem underlying the present invention is to provide compounds which can be used for the treatment of diseases which are associated with the presence of PrP<sup>Sc</sup>.

The solution to said technical problem is achieved by providing the embodiments characterized in the claims.

It has now been surprisingly and unexpectedly found that the laminin receptor precursor (LRP) specifically interacts with PrP<sup>c</sup> and PrP<sup>Sc</sup>.

In order to enlighten the normal biological function of PrP<sup>c</sup> and to search for additional cellular factors involved in prion replication, a yeast two hybrid screen was initiated and molecular chaperones of the Hsp60 family as specific interactors for PrP<sup>c</sup> could be identified (Edenhofer et al., 1996). In a more detailed analysis of the interactors of this screen, the 67 kDa laminin receptor precursor (LRP) was identified as an interactor for PrP<sup>c</sup> (PrP23-231) or PrP<sup>Sc</sup> fused to GST. The LRP/PrP interaction site was mapped. The specificity of this interaction was confirmed in insect and mammalian cells which have been co-infected with recombinant baculoviruses or co-transfected with plasmids, respectively, leading to a simultaneous expression of one of the prion proteins (PrP) and the laminin receptor precursor (LRP). The LRP/PrP interaction might be involved in proliferation of PrP<sup>Sc</sup> and, thus, by blocking this interaction, diseases associated with the presence of PrP<sup>Sc</sup> can be treated.

In the present invention, a specific interaction between the prion protein PrP<sup>c</sup> and the 67 kDa laminin receptor precursor (LRP) is reported for the first time. The receptor was identified in the yeast two-hybrid system employing a LexA-GST::PrP<sup>c</sup> fusion as the bait protein. Six different cDNAs have been isolated which encode the 67 kDa Laminin receptor precursor (LRP, Acc. No. IO-2029) lacking 43, 45, 46, 89, 130 and 156 amino acids (the latter containing 23 amino acids not homologous to the laminin receptor precursor), respectively, at the amino terminus. The specificity of this interaction was confirmed by retransformation experiments employing bait plasmids

encoding LexA-GST::PrP<sup>c</sup>, LexA-GST, LexA and the false baits LexA-CTF2 (Wendler et al., 1994) and LexA-bicoid (Gyuris et al., 1993). Only LexA-GST::PrP<sup>c</sup> bound to LRP, whereas none of the false baits interacted with the receptor. Expression of the LexA-GST::PrP<sup>c</sup> bait was confirmed by using a PrP-specific antibody. Repressor assays with lexA-GST::PrP<sup>c</sup> demonstrated that PrP<sup>c</sup> did not change the binding characteristics of the lexA binding domain.

To map the LRP binding site for PrP, prey plasmids lacking 43 amino acids up to 179 amino acids at the amino terminal end of the laminin receptor precursor were retransformed with lexA-GST::PrP<sup>c</sup>. Prey LRP $\Delta$ 157 did interact with PrP whereas LRP $\Delta$ 180 failed to bind to the prion protein demonstrating that the laminin binding domain (amino acid 161 to amino acid 180; Castronovo et al., 1991) and the PrP binding domain are identical.

In order to confirm the PrP/LRP interaction in another eukaryotic cell system, LRP (amino acid 44-amino acid 295) was expressed in baculovirus infected insect cells as a fusion with GST. Although the signal sequence of gp67 was present at the N-terminus, GST::LRP was not secreted into the culture medium but synthesized cell-associated most likely due to the presence of a short transmembrane region which was calculated between amino acid 86 and amino acid 101 of LRP (Castronovo et al., 1991a). GST::LRP which was specifically recognized by a LRP specific antibody revealed a molecular weight of 67 kDa. A polyclonal antibody directed against GST::LRP recognized recombinant LRP but revealed some background reactivity to GST. After thrombin cleavage of the fusion protein SDS gel analysis confirmed molecular weights of 37 kDa for the receptor and 27 kDa for GST. The cDNA encoding the laminin receptor precursor was initially isolated in attempts to identify the gene for the 67 kDa laminin receptor precursor (Yow et al., 1988). The cDNA, however, encoded for a 37 kDa protein (Yow et al., 1988), whereas the receptor was isolated as a 67 kDa protein from solid tumors (Malinoff and Wicha, 1983; Lesot et al., 1983; Rao et al., 1983). Pulse-Chase experiments suggest that the 37 kDa receptor could be the precursor of the 67 kDa receptor (Castronovo et al., 1991b). Homodimerization (Landowski et al., 1995) or the existence of an unknown factor (Castronovo et al., 1991b) could account for the 37/67 kDa polymorphism of the laminin receptor precursor.

Several classes of laminin binding proteins have been described including integrins (Albelda and Buck, 1990) and galactoside binding lectins. The non-integrin binding 67 kD high affinity laminin receptor precursor (LRP) binds beside laminin (Mecham et al., 1989) also elastin (Hinek et al., 1988). In order to prove the laminin binding ability of recombinant LRP fused to GST, binding assays in the presence of laminin were performed. Laminin represents a glycoprotein of the extracellular matrix (ECM) mediating cell attachment, differentiation, movement and growth (Hunter et al., 1989). Laminin was isolated from murine Engelbreth-Holm-Swarm (EHS) tumors and parietal yolk sac (PYS) carcinoma cells (for review see Mecham, 1991). For the binding assays EHS laminin was used which consists of three polypeptide chains - A or  $\alpha$  (440 kDa), B1 or  $\beta$ , and B2 or  $\gamma$  (each 220 kDa) - linked via disulfide bridges resulting in the typical cross-structure (Beck et al., 1990; Burgeson et al., 1994). Specific EHS-laminin binding to the receptor was demonstrated in the presence of GST::LRP whereas no binding occurred with GST. The Laminin/LRP interaction can be competed with FLAG::rPrP27-30 (data not shown) confirming the mapping result in *S. cerevisiae* that laminin and PrP share the same binding site on LRP (amino acids 161-180).

For co-infection assays in insect cells including GST::LRP and prion proteins, the cellular form of the hamster prion protein PrP<sup>c</sup> (PrP23-231) was synthesized and the soluble version (s) PrP27-30 of proteinase K resistant PrP27-30 (Caughey et al., 1991; Prusiner et al., 1981; 1983; 1984) was fused to the FLAG peptide. Both recombinant proteins were secreted into the culture medium, purified to homogeneity by anti-Flag-antibody affinity chromatography and recognized by a PrP specific antibody. Molecular weights determined by SDS-PAGE were 27 kDa and 17 kDa for rPrP<sup>c</sup> and rPrP27-30, respectively, and correspond to rPrP<sup>c</sup> (Weiss et al., 1995) and rPrP27-30 (Weiss et al., 1996) generated by thrombin cleavage from GST fusion proteins. In order to confirm the LRP/PrP interaction observed in *S. cerevisiae*, co-infection in Sf9 cells was performed. A specific interaction between the laminin receptor precursor and the prion protein PrP in insect cells confirms the PrP/LRP interaction observed in yeast.

To further confirm the PrP/LRP interaction in mammalian cells, FLAG::rPrP<sup>c</sup> and authentic LRP were transiently expressed in Cos-7 cells. LRP revealed a molecular

weight of 37 kDa and was recognized by a polyclonal anti-LRP antibody. rPrP<sup>c</sup> fused to FLAG showed the expected molecular weight of 27 kDa and was also recognized by a polyclonal PrP specific antibody. Interaction between both proteins was proven in Cos-7 cells demonstrating that LRP interacts with PrP in a series of different eukaryotic cells including yeast, insect and Cos-7 cells.

The laminin receptor precursor family is highly conserved in a wide spectrum of eukaryotic cells (Wewer et al., 1986; Keppel et al., 1991; Garcia-Hernandez et al., 1994), was recently reported to be present in yeast (Demianova et al., 1996) and may be encoded by archaean genomes (Ouzounis et al., 1995). The receptor works as a receptor for Sindbis Virus on mammalian cells such as CHO or BHK (Wang et al., 1992) and for Venezuelan Encephalitis Virus from Mosquito Cells (Ludwig et al., 1996). For a functional involvement of the PrP<sup>c</sup>/LRP interaction in the pathogenesis of TSEs or the biological function of PrP<sup>c</sup> one would expect that the laminin receptor precursor is present in the human brain. Therefore, the presence of LRP-specific mRNA in multiple human tissues was tested. This analysis shows that LRP-mRNA is ubiquitously distributed in several tissues including heart and brain. The size of the laminin receptor precursor mRNA of approximately 1.4 kb is identical to that found in human, rat and mouse cells (Rao et al. 1989). In addition, it has been demonstrated that the 67 kDa LRP is present on neuronal cells (Kleinmann et al., 1988; Douville et al., 1988). Moreover, laminin itself has a drastic influence on the growth of neuronal cells. The LRP works as a receptor for the Sindbis-Virus and the VEE-virus on the surface of mammalian cells. The cellular prion protein PrP<sup>c</sup> is also located on the surface of neuronal cells fixed by the glycosylphosphatidylinositol anchor (GPI; Stahl et al., 1987). Thus, a direct interaction of PrP<sup>c</sup> and LRP is conceivable on the surface of neuronal cells of the brain. To further prove whether the laminin receptor precursor is overexpressed in Scrapie infected N<sub>2</sub>a cells (Sc N<sub>2</sub>a), crude lysates of N<sub>2</sub>a and Sc N<sub>2</sub>a cells with a LRP specific antibody were analyzed. LRP is present in crude lysates of N<sub>2</sub>a cells but levels of LRP in crude lysates of Sc N<sub>2</sub>a cells are two-fold higher compared to N<sub>2</sub>a cells suggesting that LRP expression is up-regulated in N<sub>2</sub>a cells after Scrapie exposure. Recently, it has been reported that a soluble form of PrP<sup>27-30</sup> was identified in human platelets (Perini et al., 1996). sPrP<sup>27-30</sup> could work as a precursor for proteinase K resistant PrP<sup>27-30</sup>, a major product in Scrapie



infected prion-preparations (Prusiner et al., 1981; 1983; 1984). The laminin receptor precursor has also been identified in human platelets (Tandon et al., 1991) which makes a PrP/LRP interaction also conceivable in platelets.

From the above results it can be concluded that LRP is required for the proliferation of PrP<sup>Sc</sup>. A model of the function of LRP is discussed in the following section.

PrP<sup>C</sup> is synthesized at the rER and secretes via the ER, the golgi and secretory vesicles passing through the plasma membrane to the cell surface. PrP<sup>C</sup> is located on the surface of neuronal and other cells fixed by a glycosyl-phosphatidyl-inositol (GPI) anchor (Stahl et al., 1987). Treatment of the cell with phospholipase C (PIPLC) removes the diacylglycerol portion of the anchor releasing PrP<sup>C</sup> from the cell surface (Lehmann and Harris, 1996). Mutants of PrP<sup>C</sup>, however, remain bound to the membrane after PIPLC-treatment suggesting that PrP<sup>C</sup> could interact with another unknown factor (Lehmann and Harris, 1996). PrP<sup>C</sup> becomes internalized from the cell surface via clathrin coated pits (Shyng et al., 1994, 1995), caveolae or endocytosis (Taraboulos et al., 1995; Vey et al., 1996).

However, the location (secretory pathway/cell surface/endocytic pathway) where the conversion of PrP<sup>C</sup> to PrP<sup>Sc</sup> occurs remains unclear. PrP<sup>Sc</sup> reaches the brain of TSE infected individuals via nerve cells or via the blood brain barrier. PrP<sup>Sc</sup> could be transported from the periphery to the nerve cells by cells of the lymphatic system (such as B-lymphocytes which have been proven to be essential for prion propagation (Klein et al., 1997)) including the spleen, the peripheral nervous system (PNS) and the central nervous system (CNS) including the spinal cord. These cells might bind PrP<sup>Sc</sup> via LRP. PrP<sup>Sc</sup> could either bind to PrP<sup>C</sup> on the cell surface in the absence or presence of an unknown receptor as suggested by Harris (Lehmann and Harris, 1996) such as the laminin receptor precursor. PrP<sup>C</sup>/PrP<sup>Sc</sup> binding could be dependent on the presence of the laminin receptor precursor. Membrane trafficking of PrP<sup>C</sup> and PrP<sup>Sc</sup>, either separately or complexed, can also be mediated by the laminin receptor precursor. The uptake of both PrP molecules can occur, either complexed or separately, by clathrin coated pits (Shyng et al., 1994, 1995).

endocytosis or caveolae (Taraboulos et al., 1995; Vey et al., 1996). Heterodimeric complexes are formed in early endosomes, transport vehicles and endolysosomes. Lysosomes (Caughey et al., 1992; Taraboulos et al., 1992) are thought to contain predominantly PrP<sup>Sc</sup> (Caughey et al., 1991). It is thought that PrP<sup>c</sup> is still GPI anchored in endosomes, endolysosomes and lysosomes.

There is evidence that some early steps in the generation of PrP<sup>Sc</sup> from mutant PrPs might take place in the ER or Golgi (Lehmann and Harris, 1996). Mutant PrP could be attached to the cell membrane in addition to the GPI-anchor via a transmembrane region or an additional receptor (Lehmann and Harris, 1996). LRP is most likely located on the cell surface since it was proven that LRP acts as a receptor for the Sindbis virus on mammalian cells such as BHK cells (Wang et al., 1992). Recently, it was shown that the Venezuelan Equine Encephalitis Virus (VEE) also uses LRP on the surface of mosquito cells. Thus LRP and PrP<sup>c</sup> could share the same location on the surface of the cell.

In the present invention it was observed, in addition, that LRP is overexpressed in Scrapie infected neuroblastoma cells. The binding of PrP<sup>Sc</sup> to LRP could lead to the induction of LRP expression via a second messenger (maybe cAMP coupled) or an alternative mechanism. Alternatively, it is conceivable that PrP<sup>Sc</sup> prevents LRP from degradation. The high concentration of LRP makes it likely that LRP is affiliated with PrP propagation by interacting with PrP<sup>c</sup> or PrP<sup>Sc</sup> or both (Fig. 7). Thus, by inhibiting said interaction using a soluble LRP or by trapping PrP<sup>Sc</sup> diseases associated with the presence of PrP<sup>Sc</sup> can be treated.

Accordingly, the present invention relates to a pharmaceutical composition comprising a soluble LRP, a mutein, fused protein, salt, functional derivative or fragment thereof, that can bind to PrP<sup>Sc</sup>, PrP<sup>c</sup> or fragments thereof. Said composition might be useful for the treatment of diseases associated with the presence of PrP<sup>Sc</sup>.

The soluble part of the LRP corresponds to the extracellular domain of LRP comprising the region from amino acid no. 101 to no. 295 of the amino acid

sequence disclosed in Yow et al., 1988 (see Figures 3 and 4 and pages 6396 and 6397). It is, however, apparent for the person skilled in the art that for the preparation of the above pharmaceutical composition not only the soluble part of LRP with the amino acid sequence disclosed in Yow et al., 1988, can be used, but, in addition, a mutein of said soluble LRP, a fused protein, salt, functional derivative or fragment thereof which are still capable of binding PrP<sup>Sc</sup> or PrP<sup>C</sup>.

As used herein, the term "muteins" refers to analogs of the soluble LRP in which one or more of the amino acid residues of the soluble LRP described in Yow et al., 1988, are replaced by different amino acid residues or are deleted, or one or more amino acid residues are added without considerably changing the activity of the resulting product. These muteins are prepared by known synthesis and/or by site-directed mutagenesis techniques, or any other known technique suitable therefor.

The term "fused protein" refers to a polypeptide comprising a soluble LRP according to the invention, or a mutein thereof fused with another protein which has an extended residence time in body fluids. The soluble LRP may thus be fused to another protein, polypeptide or the like, e.g., an immunoglobulin or a fragment thereof.

The term "salts" herein refers to both salts of carboxyl groups and to acid addition salts of amino groups of a soluble LRP, muteins and fused proteins thereof. Salts of a carboxyl group may be formed by means known in the art and include inorganic salts, for example, sodium, calcium, ammonium, ferric or zinc salts, and the like, and salts with organic bases as those formed, for example, with amines, such as thiethanolamine, arginine or lysine, piperidine, procaine and the like. Acid addition salts include, for example, salts with mineral acids such as, for example, hydrochloric acid or sulfuric acid, and salts with organic acids such as, for example, acetic acid or oxalic acid.

"Functional derivatives" as used herein cover derivatives of a soluble LRP and its fused proteins and muteins, which may be prepared from the functional groups

which occur as side chains on the residues or the N- or C-terminal groups, by means known in the art, and are included in the invention as long as they remain pharmaceutically acceptable, i.e. they do not destroy the activity of the protein and do not confer toxic properties on compositions containing it. These derivatives may, for example, include polyethylene glycol side-chains which may mask antigenic sites and extend the residence of a soluble LRP in body fluids. Other derivatives include aliphatic esters of the carboxyl groups, amides of the carboxyl groups by reaction with ammonia or with primary or secondary amines, N-acyl derivatives of free amino groups of the amino acid residues formed with acyl moieties (e.g. alkanoyl or carbocyclic aroyl groups) or O-acyl derivatives of free hydroxyl groups (for example that of seryl or threonyl residues) formed with acyl moieties.

As "fragment of the soluble LRP", its fused proteins and its muteins, the present invention covers any fragment of the polypeptide chain of the protein molecule alone or together with associated molecules or residues linked thereto, e.g. sugar or phosphate residues, or aggregates of the protein molecule or the sugar residues by themselves, provided said fraction has the same biological activity and/or pharmaceutical activity.

By using standard assays described in the literature, the person skilled in the art can easily check whether the above compounds are capable of binding PrP<sup>Sc</sup>, PrP<sup>C</sup> or fragments thereof.

The term "fragment of PrP<sup>Sc</sup> or PrP<sup>C</sup>" herein refers to any fragment of the polypeptide chain of the protein which can bind to the LRP.

The above pharmaceutical compositions may be prepared by any of the well known procedures in which the active ingredient, soluble LRP, is optionally admixed with pharmaceutically acceptable diluents, carriers or excipients. Actual dosages and modes of administration of such pharmaceutical compositions will be determined by the professional practitioners.

In addition, the present invention relates to a pharmaceutical composition comprising a compound that blocks the interaction of LRP and PrP<sup>Sc</sup>, PrP<sup>C</sup> or fragments thereof and, optionally, a suitable diluent, carrier and/or excipient. Such compounds can be identified, for example, by the screening system described below.

In a preferred embodiment, said compound is an antibody, preferably a monoclonal antibody, or a fragment thereof which binds to the surface epitope of LRP in such a way that binding of PrP<sup>Sc</sup>, PrP<sup>C</sup> or fragments thereof is no longer possible. Alternatively, the antibody binds to PrP<sup>Sc</sup>, PrP<sup>C</sup> or fragments thereof, thus blocking the LRP/PrP interaction.

Such antibodies or fragments thereof can be prepared according to standard procedures. Antibodies directed, for example, to the soluble part of LRP may be serum-derived (polyclonal) or monoclonal. For example, monoclonal antibodies are prepared using hybridoma technology by fusing antibody producing B cells from immunized animals with myeloma cells and selecting the resulting hybridoma cell line producing the desired antibody. Alternatively, synthetic peptides may be prepared using the amino acid sequence described in Yow et al., 1988. As a further alternative, DNA, such as a cDNA or a fragment thereof, may be cloned and expressed and the resulting polypeptide recovered and used as an immunogen. These antibodies are useful to inhibit the function of the LRP. Particularly useful are antibodies binding to the PrP binding domain of LRP (amino acids 161 to 180).

In a further preferred embodiment, said compounds which block the interaction of LRP and PrP<sup>Sc</sup> or PrP<sup>C</sup> comprise:

- (1) peptides encoded by a peptide library,
- (2) proteins encoded by a cDNA library, for example, derived from brain tissue or other appropriate organs,
- (3) components of organic or anorganic nature synthesized chemically, including nucleic acids.

Among the above compounds those that inhibit the interaction between LRP and PrP<sup>Sc</sup> or PrP<sup>c</sup> can be identified, for example, by a reverse two-hybrid system. The reverse two-hybrid system (Fig. 8) modified from Leanna and Hannink, 1996, represents a straightforward method for the identification of compounds blocking the LRP/PrP interaction. The reverse Gal4/LexA two-hybrid system is a genetic selection scheme that selects against the association of PrP fused to the DNA binding domain Gal4/LexA and LRP fused to the activation domain of Gal4 or the acidic activation domain of B42. Association of Gal4::PrP/LexA/PrP and Gal4AD:LRP/B42:LRP results in the localization of the Gal4/B42 activation domain to the Gal1/LexA promoter and in the expression of CYH2. Survival of the CHX-resistant *cyh2* yeast strain grown on plates containing CHX is dependent upon the lack of association of the PrP<sup>c</sup> and LRP fusion proteins in the "bait" and "prey" position. The inhibitor can represent a compound added to the culture medium or a peptide expressed from a peptide cDNA library additionally transformed into the yeast strain. An additional selection marker (i.e. *His*) is necessary to select on the presence of the cDNA library. This system is described in more detail in Example 1, below.

Alternatively, the mammalian two-hybrid system (supplied by CLONETECH Laboratories Inc., USA) can be used to screen for therapeutics interfering with the LRP/PrP interaction (Fig. 9). PrP can be fused to the DNA binding domain of Gal4 (bait plasmid). LRP can be fused to VP16, the herpesvirus transactivator in the prey position (prey plasmid). The interaction of bait and prey will lead to activation of transcription of the CAT reporter gene (supplied by a reporter plasmid) by RNA polymerase II from the minimal promoter of the adenovirus E1 b gene. Alternatively, luciferase can be used as a reporter gene enhancing the sensitivity of the assay.

Compounds can be screened using, for example, peptide libraries which can be co-transfected into mammalian cells using a selection marker such as neomycin (leading to viable cells in the presence of G 418). Compounds can easily be added to the culture medium. In contrast to the yeast system, mammalian cells are lacking a cell wall so that the uptake/intake of the compounds is much more efficient compared to yeast. In addition, mammalian cells represent the highest phylogenetic

system with the highest degree in glycosylations, phosphorylations and other posttranslational modifications. The toxicity of a compound is assayed simultaneously in the mammalian system, whereas the toxicity of a component directed against the LRP/PrP interaction in the yeast two-hybrid system has to be re-assayed in the mammalian system for toxicity.

In addition, the yeast and the mammalian systems can be altered with respect to simplifying the screening assay. cDNA encoding LRP and PrP<sup>c</sup> can be cloned into the bait position either in a co-directional or opposite direction leading to the expression of both proteins from a single plasmid. The cDNA library encoding for peptides or other presumable PrP/LRP interfering components can be cloned into the prey position so that no additional plasmid has to be transformed or transfected into the yeast or mammalian cells, respectively.

Accordingly, the present invention also relates to pharmaceutical compositions comprising a compound identified by the method described above.

The above pharmaceutical compositions might be useful for the treatment of diseases associated with the presence of PrP<sup>Sc</sup>. Examples of such diseases are the transmissible spongiform encephalopathies, such as scrapie, bovine spongiform encephalopathy, Creutzfeldt-Jakob disease, Fatal Familial Insomnia, chronic wasting disease and feline spongiform encephalopathy (FSE).

Moreover, diseases associated with the presence of PrP<sup>Sc</sup> can be treated by blocking the synthesis of LRP, e.g. by applying an antisense-RNA or a ribozyme which can bind/cleave the mRNA encoding LRP, thus inhibiting translation, and expression of LRP.

The application of suitable antisense RNAs or ribozymes, including the transformation of cells and the construction of expression vectors, can be carried out by methods well known to the person skilled in the art, e.g. by the techniques described in Example 9, below.

Thus, the present invention also relates to pharmaceutical compositions comprising an antisense-RNA or ribozyme which blocks the expression of the LRP.

In addition, the present invention provides an expression vector for the recombinant production of LRP or any other kind of protein in the baculovirus system, pFLAG::BAC. The protein will be synthesized in the fusion with a FLAG-tag at the aminoterminal end of the protein. The FLAG-tag can be cleaved off employing the specific protease enterokinase. The recombinant protein will be secreted into the culture medium due to the presence of the signal sequence gp67. Proteins of any kind expressed in the fusion with FLAG in the baculovirus system can be phosphorylated and glycosylated, although it is known that the baculovirus system cannot form high-branched sugars. FLAG will enhance the solubility and stability of the fusion protein. This vector has the structure shown in Figure 13 and the nucleic acid sequence shown in Figure 14 or substantially said sequence.

The term "substantially", as used herein, refers to a nucleic acid sequence in which one or more nucleotides of the nucleic acid sequence shown in Figure 14 are replaced by different nucleotides or are deleted, or one or more nucleotides are added without considerably changing the biological properties of the vector as regards the capability (i) of replicating in the baculovirus system, (ii) of expressing the heterologous protein, (iii) of allowing the secretion of the protein in the culture medium and/or (iv) of providing the heterologous protein in a soluble and stable form. The nucleic acid sequence which has "substantially" the sequence shown in Figure 14 has at least 90%, preferably at least 95%, more preferably at least 98% and most preferably at least 99% homology to said sequence. Such a sequence is prepared by known synthesis and/or by site-directed mutagenesis techniques or any other known technique suitable therefor. The biological properties (i) and (iv) of a vector having such a sequence can be assayed by the skilled person using routine methods.



## Legends to the figures

### Fig. 1: Identification of the PrP<sup>Sc</sup> 67 kDa LRP interaction in the yeast two-hybrid system in *S. cerevisiae*.

Yeast cells containing the reporter plasmid pSH18-34 were cotransformed with prey plasmid pJG4-5Δ43 encoding LRP (amino acids 44-295) encoding cDNA and the bait plasmids pSH2-1-GST::rPrP<sup>Sc</sup> (row 1), pSH2-1-GST (row 2), pSH2-1 (row 3), pSH2-1-CTF-2 (row 4; Wendler et al., 1994) and pEG202-bicoid (row 5; Gyuris et al., 1993). Resuspension of each of the five transformants was carried out in TE and dotted onto galactose plates which were either supplemented with X-gal (a) or leucine deficient (b). Plates were incubated for 3 days at 30°C.

### Fig. 2: Mapping of the PrP/LRP interaction site in the yeast two-hybrid system

Yeast cells containing the reporter plasmid pSH18-34 were cotransformed with the bait plasmid pSH2-1-GST-PrP<sup>Sc</sup> and prey plasmids pJG4-5Δ43 (row 1), pJG4-5Δ45 (row 2), pJG4-5Δ46 (row 3), pJG4-5Δ89 (row 4), pJG4-5Δ130 (row 5), pJG4-5Δ156 (row 6) and pJG4-5Δ179 (row 7) coding for amino terminal truncated versions of the laminin receptor precursor lacking 43, 45, 46, 89, 130, 156 amino acids (the latter contains 23 amino acids not homologous to the laminin receptor precursor) and 179 amino acids (lacking the laminin binding domain) at the amino terminus. Each of five transformants were resuspended in TE, dotted on X-Gal supplemented plates and incubated at 30°C for 3 days.

### Fig. 3: Analysis of recombinant LRP fused to GST in baculovirus infected insect cells (Sf9)

(a) Protein fractions from the supernatant (lane 1) and the cell pellet (lane 2) of  $1.5 \times 10^7$  Sf9 cells infected with AcSG2T-LRP were purified by glutathione sepharose chromatography and analyzed on a 12.5 % SDS-gel. (b) Western Blot analysis of (a) using a polyclonal LRP specific antibody. (c) Analysis of the interaction of

recombinant LRP with Engelbreth-Holm-Swarm (EHS) laminin. 50  $\mu$ l each of glutathione sepharose beads (lane 1), coupled with 37 pMol GST (lane 2), or 37 pMol GST::LRP (lane 3) were incubated with 17.5 pMol EHS laminin. Complexes were analyzed on 12.5 % in TCM buffer, reactions were carried out overnight at 4°C, beads subsequently washed four times with TCM and analyzed on SDS-PAGE gels AgNO<sub>3</sub> stained. Two micrograms each of the individual marker proteins (rainbow marker RPN 756; lane M) and 3  $\mu$ g of EHS-laminin (lane 4) were loaded.

Fig. 4: (a) Northern Blot Analysis of multiple human tissues, and (b) and (c) Western Blot Analysis of crude lysates of N<sub>2</sub>a/ScN<sub>2</sub>a cells

Total mRNA isolated from human heart (lane 1), brain (lane 2), placenta (lane 3), lung (lane 4), liver (lane 5), skeletal muscle (lane 6), kidney (lane 7) and pancreas (lane 8) was immobilized on a nylon membrane and probed with a radiolabelled DNA fragment corresponding to 550 bp of the human 67 kDa high affinity laminin receptor precursor cDNA. (bottom) Total mRNA as described above was assayed with a radiolabelled  $\beta$ -actin probe.

(b) Western blot analysis of crude lysates from N<sub>2</sub>a and ScN<sub>2</sub>a cells employing an LRP specific antibody (anti-LBP (laminin-binding protein) antibody, provided by Dr. Starkey, Montana, USA, see below 8. Antibodies). 25  $\mu$ l each of crude lysates of N<sub>2</sub>a (lane 2) and ScN<sub>2</sub>a (lane 3) cells and 500 ng of recombinant GST::LRP were analyzed on SDS-PAGE, blotted onto PVDF membrane and developed by a LRP specific antibody.

(c) Western blot analysis of crude lysates from N<sub>2</sub>a and ScN<sub>2</sub>a cells employing an LRP specific antibody prepared as described below (page 26; 8. Antibodies). 20  $\mu$ l each of crude lysates from N<sub>2</sub>a (lane 2) and ScN<sub>2</sub>a (lane 3) cells were analyzed on a 12.5 % SDS-PAGE gel, blotted onto a nitrocellulose membrane and developed with (a) a LRP specific antibody and (b) a monoclonal anti- $\beta$ -actin antibody. Two

micrograms of the individual marker proteins (rainbow marker RPN 756, Amersham; lane 1) were loaded.

**Fig. 5: Analysis of PrP/LRP interactions by Co-infection assays in baculovirus infected insect cells (Sf9)**

(a) Secretion of FLAG::rPrP23-231 (rPrP<sup>c</sup>) and FLAG::rPrP90-231 from Baculovirus infected insect cells. Protein extracts from the supernatant of FLAG-BAC::rPrP23-231 and FLAG-BAC::rPrP90-231 (rPrP27-30) infected insect cells ( $1.5 \times 10^7$ ) were purified by anti-FLAG-antibody affinity chromatography. 500 ng each of FLAG::rPrP23-231 (rPrP<sup>c</sup>) (lane 1) and FLAG::rPrP90-231 (rPrP27-30) (lane 2) were analyzed by western blotting developed by a polyclonal anti-PrP antibody. (b) Sf9 cells were co-infected with FLAG-BAC::rPrP23-231 and AcSG2T::LRP (lane 3), FLAG-BAC::rPrP23-231 and AcSG2T (lane 1), FLAG-BAC::rPrP90-231 (rPrP27-30) and AcSG2T (lane 4) and FLAG-BAC::rPrP90-231 (rPrP27-30) and AcSG2T (lane 2). GST and GST fusion proteins interacting with FLAG::rPrP23-231 and FLAG::rPrP90-231, respectively, have been isolated and purified by anti-FLAG-antibody affinity chromatography and analyzed by Western Blotting employing a polyclonal GST antibody.

**Fig. 6: Analysis of PrP/LRP interactions by Co-transfection assays in Cos-7 cells**

(a) Expression of FLAG::rPrP23-231 from hamster in Cos-7 cells. Lane 1: 500 ng of FLAG::rPrP23-231 purified from transiently transfected Cos-7 cells were analyzed by Western Blotting with an PrP specific antibody. (b) Co-transfection assay. Lane 2: Cos-7 cells were co-transfected with pFLAG-CMV-2::rPrP23-231 and pcDNA3::LRP. Cos-7 cells were transfected with pFLAG-CMV-2::rPrP23-231 (lane 1) or pcDNA3::LRP (lane 3). Crude lysate from pcDNA3::LRP transfected cells was analyzed by Western Blotting with a LRP specific antibody. LRP interacting with FLAG::rPrP23-231 was isolated and purified by anti-FLAG-antibody chromatography and analyzed by immunoblotting employing a polyclonal LRP antibody.

Fig. 7: Model of the function of the LRP as the receptor for the prion proteins PrP<sup>c</sup> and/or PrP<sup>Sc</sup>

Endocytosis of PrP<sup>c</sup> and eventually PrP<sup>Sc</sup> via caveolae like domains or clathrin coated pits could be laminin receptor precursor (LRP) mediated. Conversion of PrP<sup>c</sup> to PrP<sup>Sc</sup> is thought to take place in the endolysosomes or lysosomes of the cell. Molecular chaperones are thought to be involved in that process. PrP replications can occur in brain cells such as neuroblastoma cells but also in other cells of the organism such as spleen and pancreatic cells. B-lymphocytes are thought to play a crucial role in transporting PrP<sup>Sc</sup> to the nerve cell.

Fig. 8: Schematic presentation of the reverse two-hybrid system to screen for components interfering with the LRP/PrP<sup>c</sup> interaction

Fig. 9: Schematic presentation of the mammalian two-hybrid system to screen for components interfering with the LRP/PrP<sup>c</sup> interaction

Fig. 10: Localization of the 67 kDa high affinity laminin receptor precursor in the plasma membrane

The N-terminus of the receptor is thought to be located in the cytoplasm of the cell (Castronova et al., 1991). A short transmembrane region was also suggested between amino acid 88 and amino acid 101 of LRP (Mohane and Argos, 1986). The carboxy terminus of LRP is thought to be located extracellularly. A short laminin binding domain was identified between amino acid 161 and amino acid 180 of LRP corresponding to the PrP binding domain (Rieger et al., 1997, and Castronovo et al., 1991).

Fig. 11: Targeted disruption of the LRP gene locus by homologous recombination and introduction of an Anti-LRP gene for antisense RNA production

Structure of the replacement vector (A), the hypothetical genomic structure of one LRP gene locus (B) and the mutated locus with the inserted antisense-LRP cassette (C). In the replacement vector parts of the exon will be replaced by the antisense-LRP cassette under the control of an inducible promoter (metallothionine promoter, tetracycline-responsive promoter) adjacent to the neomycin resistance cassette (NEO). The negative selection marker thymidine kinase (TK) will be added to one site of the homology region. Splinkers should be ligated to the linearized vector to prevent vector degradation by endonucleases. Shown are the probes for Southern blot analysis (probe A, Anti-LRP probe, Neoprobe). PCR primers to identify homologous recombined ES cell clones and predicted fragments after restriction enzyme (RE B, RE C, RE D) analysis are indicated. P<sub>ind</sub> = inducible promoter.

Fig. 12: Generation of LRP knock-out mice

(A) ES-cells isolated from the inner cell mass of an early blastocyte are transfected with a replacement vector to produce ES-cell clones mutated on one allele of the LRP gene.

(B) Homologous recombined ES-cell clones were transferred into a mouse embryo via morula aggregation or blastocyst injection. Chimeras were assayed for germ line integration of the disrupted LRP gene by coat color and Southern blot analysis. Homozygous mice were obtained by inbreeding heterozygous mice. Abbreviations are: ICM, inner cell mass; ES, embryonic stem; LIF, leukaemia inhibitory factor.

**Fig. 13: Structure of the vector pFLAG:BAC**

The map shows the position of the polyhedrin promoter, the signal sequence of gp67, the polylinker, the origin of replication and the gene conferring resistance to ampicillin.

**Fig. 14: Nucleic acid sequence of pFLAG:BAC with restriction sites****Fig. 15: Co-expression of FLAG-tagged Hsp60 and GST-tagged prion proteins from Syrian golden hamster in the baculovirus system**

Cell lysates were analyzed on 12.5% SDS gel. Western Blotting employing a monoclonal anti-FLAG M2 antibody shows decreased levels of FLAG::Hsp60 when co-expressed with GST::haPrP<sup>Sc</sup>23-231 (lane 3) and GST::haPrP<sup>Sc</sup>90-231 (lane 4) compared to FLAG::Hsp60 expression (lane 1) and co-expression of GST control (lane 2).

**Fig. 16: Western Blot analysis of brain and spleen homogenates from scrapie (strain C506M3) infected, BSE (strain 4PB1) infected and uninfected mice.**

20 µl each of homogenates (corresponding to 0.5 mg of tissue) from brain of scrapie infected (lane 2), BSE infected (lane 6) and uninfected mice (lanes 3 and 7, respectively), 20 µl each of crude lysates from spleen of scrapie infected (lane 4), BSE infected (lane 8) and uninfected mice (lanes 5 and 9, respectively) were analyzed on 12.5 % PAA-gels and developed with (a) an LRP specific antibody and (b) a monoclonal anti-β-actin antibody. Two micrograms of the individual marker proteins (rainbow marker RPN 756, Amersham; (a, b) lanes 1) were loaded. Sc, BSE and N denotes Scrapie, BSE and not infected, respectively.

**Fig. 17: Western Blot analysis of homogenates of brain, spleen, pancreas, liver and skeletal muscle from scrapie (strain 263 K) infected and uninfected hamsters.**

20 µl each of the homogenates (corresponding to 0.5 mg of tissue) of brain (lane 2), spleen (lane 4), pancreas (lane 6), liver (lane 8), skeletal muscle (lane 10) from Scrapie infected hamsters and 20 µl each of the homogenates of brain (lane 3), spleen (lane 5), pancreas (lane 7), liver (lane 9), skeletal muscle (lane 11) from uninfected hamsters were analyzed on 12.5 % SDS PAA-gels and developed with a LRP specific antibody (a), a monoclonal anti-B-actin antibody (b, left panel) and a monoclonal anti-actin antibody (b, right panel). Two micrograms of the individual marker proteins (rainbow marker RPN 756, Amersham; (a, b lanes 1) were loaded. Sc and N denotes Scrapie and not infected, respectively.

The results shown in Figures 16 and 17 are summarized in Table 1, below.

**Fig. 18: Localization of LRP on the surface of neuroblastoma cells**

(for details see Example 10)

**Fig. 19: The Uptake of recombinant Prion Proteins from cattle by murine neuroblastoma cells (N<sub>2</sub>a)**

N<sub>2</sub>a cells were incubated with bovine PrP fused to GST expressed in the baculovirus system. Cells were incubated with a PrP specific antibody (3B5) Magnification: 400 fold (A). A LRP specific antibody (Rieger et al., 1997) was preincubated before the recombinant bovine PrP was added to the cells followed by addition of a PrP specific antibody (3B5) Magnification 630: fold (B).

The invention will now be illustrated by the following examples. It should be noted that, unless otherwise indicated, the methods described in the examples are standard, well establishing methods, widely used in molecular biology. Accordingly, reference will be made to various publications in which the methods are fully detailed. Further, where details are provided concerning manufacturers, it is to be understood that the associated methods are according to the manufacturer's protocols.

General methods used in the Examples described below:

**1. Repression assay:**

Each of the bait plasmids pSH-GST-PrP<sup>c</sup>, pSH-2-1-CTF-2 and pEG202-bicoid were separately cotransformed with pJK101 (Gyuris et al., 1993), a reporter plasmid harboring LexA binding sites in the operator region of a lacZ reporter gene. In case of correct folding and transport in the nucleus the LexA fusion protein switches off the reporter gene resulting in white color of the colonies. Control of bait protein expression: Yeast cultures transformed with pSH-GST-PrP<sup>c</sup> or pSH-GST were incubated for 2 days at 30° C. Cells were lysed in sample buffer and analyzed by SDS-PAGE and immunoblotting employing a hamster PrP-specific antibody.

**2. Plasmid constructions:**

Cloning procedures were performed as described previously (Sambrook et al., 1989) unless otherwise stated.

(i) *Construction of pAcSG2T::LRP.* The LRP (amino acid 44 to amino acid 295 of human 67 kDa high affinity laminin receptor precursor, accession no. IO2029) encoding cDNA was amplified by PCR from prey-plasmid pJG4-5 III.93 introducing a *Bam*HI and a 3' *Eco*RI-restriction site at the 5' and 3' end, respectively. The 768 bp fragment was cloned into baculovirus transfection vector pAcSG2T (Wang et al., 1995) via these two restriction sites resulting in pAcSG2T::LRP which was confirmed by dideoxysequencing.

(ii) *Construction of pFLAG-BAC.* A DNA fragment encoding the carboxy terminus of the gp67 signal sequence (Whiteford et al., 1989) followed by the FLAG-tag (Asp-Tyr-Lys-Asp-Asp-Asp-Lys) flanked by a *Spe*I (5') and a *Bam*HI (3') restriction site was PCR amplified from pAcGP67 B (Pharmingen) using oligodeoxyribonucleotide 1 (5' CTATGCTACTAGTAAATCAGTCAC 3') and oligodeoxyribonucleotide 2 (5'



CCCATGGCCCGGGATCCCTTGTCATCGTCGTCCTTGTAGTCCGC

AAAGGCAGAATGCGC 3'; the sequence encoding the FLAG-tag is underlined). The 139 bp DNA fragment was subcloned via *SpeI* and *Bam*HI restriction sites into pAcGP67 B resulting in the baculovirus transfer vector pFLAG::BAC (9780 bp) which was proven by dideoxysequencing.

(iii) *Construction of pFLAG-BAC::rPrP23-231 (rPrP<sup>c</sup>)* The rPrP23-231 (rPrP<sup>c</sup>) cassette (648 bp) was excised from pAcSG2T::PrP<sup>c</sup>23-231 (Weiss et al., 1995) via *Bam*HI and *Eco*RI at the 5' and 3' end, respectively, subcloned into pFLAG-BAC resulting in pFLAG-BAC::rPrP23-231 (rPrP<sup>c</sup>) (10406 bp) which was confirmed by dideoxysequencing.

(iv) *Construction of pFLAG-BAC::rPrP90-231 (rPrP27-30)*. cDNA encoding for rPrP90-231 (rPrP27-30) (447 bp) was restricted from pAcSG2T::rPrP27-30 (Weiss et al., 1996) with *Bam*HI (5') and *Eco*RI (3') and subcloned into pFLAG-BAC. The resulting transfer vector pFLAG-BAC::rPrP90-231 (rPrP27-30) (10205 bp) was confirmed by dideoxysequencing.

(v) *Construction of pcDNA3::LRP*. The LRP (amino acid 44 to amino acid 295 of human 67 kDa high affinity receptor, accession no. I02029) encoding cDNA was amplified by PCR from expression plasmid pAcSG2T::LRP introducing a *Bam*HI and a *Eco*RI restriction site at the 5' and 3' end, respectively. The 844 bp fragment was cloned into mammalian expression vector pcDNA3 via these two restriction sites resulting in pcDNA3::LRP which was confirmed by dideoxysequencing.

(vi) *Construction of pFLAG-CMV-2::rPrP23-231 (rPrP<sup>c</sup>)*. A 97 bp DNA fragment encoding the N-terminal part of haPrP23-231 flanked by a *Hind*III (5') and *Sau*I (3') restriction site was PCR amplified from pAcSG2T::rPrP23-231 (Weiss et al., 1995). A 558 bp DNA fragment encoding the carboxy terminus of haPrP23-231 was excised from pAcSG2T::rPrP23.231 (Weiss et al., 1995) via *Sau*I (5') and *Eco*RI (3'). Both fragments were subcloned via *Hind*III and *Eco*RI into pFLAG-CMV-2 (Eastman Kodak Co.) resulting in the mammalian expression vector pFLAG-CMV-2::rPrP23-231 (5302 bp).

### 3. Insect cell and Virus culture:

Cultures of *spodoptera frugiperda* (Sf9 cells) and infections by recombinant baculoviruses were performed as described previously (King and Possee, 1992; O'Reilly et al., 1992). Cotransfections employing 2 µg of pAcSG2T-LRP, pFLAG-BAC::rPrP23-231 (rPrP<sup>c</sup>) and pFLAG-BAC::rPrP90-231 (rPrP27-30), respectively, and 0.5 µg of linearized baculovirus DNA were done as recently reported for GST::rPrP<sup>c</sup> and GST::rPrP27-30 (Weiss et al., 1995; 1996). Purified plaques were used to screen for the expression of GST::LRP, FLAG::rPrP23-231 (FLAG::rPrP<sup>c</sup>) and FLAG::rPrP90-231 (FLAG::rPrP27-30) by SDS-PAGE and Western blotting. Recombinant virus stocks were amplified by picking plaques followed by reinfections of adherent Sf9 cultures in SF900II in the absence of FCS. After several passages the recombinant virus stock reached 10<sup>7</sup>-10<sup>8</sup> PFU/ml. Infections for the synthesis of recombinant protein were performed as described (Weiss et al., 1995; 1996). For protein synthesis as well as for virus stock amplification a multiplicity of infection (MOI) of 1 was used. For protein synthesis, medium containing FLAG::rPrP or cells containing GST::LRP were collected 72 h p.i. For the preparation of virus stocks, supernatants were harvested 4 to 7 days p.i.

### 4. Co-infection studies in Sf9 cells:

FLAG tagged rPrP23-231 (rPrP<sup>c</sup>) (Fig. 5 a, lane 1) and FLAG::rPrP90-231 (rPrP27-30) (Fig. 3 a, lane 2) secreted from baculovirus infected insect cells display molecular weights of 27 kDa and 17 kDa, respectively. GST::LRP can only be detected with a GST specific antibody upon co-infection with FLAG-tagged rPrP<sup>c</sup> (Fig. 5 b, lane 1) and FLAG::rPrP27-30 (Fig. 3 b, lane 3). GST alone, however, is not detectable upon coinfection with FLAG-tagged rPrP<sup>c</sup> (Fig. 3 b, lane 2) and FLAG::rPrP27-30 (Fig. 3 b, lane 4) or FLAG tagged controls, i.e. Src kinase p59hck (data not shown).

## 5. Mammalian cell culture, transfection and co-transfection studies:

Cos-7 cells (ATCC # CRL 16512) were maintained as monolayer cultures in D10 medium (Dulbecco-modified Eagle media containing 10% fetal calf serum, 1% glutamine, 100 µg/ml penicillin, 100 µg/ml streptomycin as recommended by the manufacturer, Seromed).  $1 \times 10^7$  monolayered cells were either separately or simultaneously transiently transfected with 8 µg each of pcDNA3::LRP and pFLAG-CMV-2::rPrP23-231, respectively, using the lipofectamine transfection method according to the supplier's protocol (Gibco BRL). As a transfection control  $1 \times 10^7$  Cos-7 cells in monolayer culture were transiently transfected with pAAVRnlacZ (Chiorini et al., 1995) containing a nuclear-localized *LacZ* gene promoted by the Rous sarcoma virus long terminal repeat (RSV LTR) and flanked by an AAV ITR sequence. Cells expressing LRP and/or FLAG::rPrP<sup>c</sup> were lysed 48 hr post transfection in 300 µl of PBS containing 0.1% Triton X-100. Lysates were either directly analyzed by SDS-PAGE and Western Blotting or in the case of an transfection assay with pFLAG-CMV-2::rPrP23-231 or co-transfection assay incubated overnight at 4°C with 100µl of a 1:1 slurry of anti-FLAG antibody-coupled agarose (Eastman Kodak) pre-equilibrated with PBS containing 0.1% Triton-X-100. The beads were subsequently washed in PBS and analyzed by SDS-PAGE and immunoblotting employing the anti-LRP antibody.

## 6. Purification of GST::LRP:

For the purification of GST::LRP from AcSG2T::LRP infected Sf9 cells, cells were harvested 72-h-p.i. by centrifugation (700 x g for 10 min at 4°C), washed with PBSd (Weiss et al., 1995) and resuspended in PBSd supplemented with 0.1% Triton-X-100 at 4°C. Cells were lysed by centrifugation at 15000 x g for 10 min at 4°C and the protein from the supernatant immobilized by addition of 500 µl (per  $1.5 \times 10^7$  cells) of a 1:1 slurry of glutathione-Sepharose beads (delivered by Pharmacia and

equilibrated in PBSd). After being shaken overnight at 4°C, beads were washed four times with 10 column volumes of PBSd and stored as a 1:1 slurry in PBSd at 4°C. GST::LRP was eluted from glutathione sepharose beads by competition with 18.3 mM reduced glutathione and shaking at 4°C overnight. Soluble protein was separated from the beads by centrifugation and analyzed by SDS-PAGE and immunoblotting. If desirable, glutathione can be removed by dialysis. The purification of recombinant GST::LRP from the culture medium was performed as described for the purification of FLAG tagged proteins.

**7. Purification of FLAG::rPrP23-231 (rPrP<sup>c</sup>), FLAG::rPrP90-231 (rPrP27-30) and FLAG::Hsp60 from insect cells:**

In order to purify FLAG::rPrP23-231 and FLAG::rPrP90-231 from either FLAG-BAC::rPrP23-231 or FLAG-BAC::rPrP90-231 infected Sf9 cells were harvested and lysed as described above. FLAG tagged protein from the supernatant of  $1.5 \times 10^7$  cells was immobilized by the addition of 200  $\mu$ l of a 1:1 slurry of Anti-FLAG M2 affinity gel over night at 4°C. Beads were washed four times with PBSd and directly analyzed by SDS-PAGE and immunoblotting (for protein analysis or the proof of protein-protein interactions). Soluble FLAG::rPrP<sup>c</sup> and FLAG::rPrP27-30 was obtained by eluting the protein from the anti-FLAG affinity column by competition with 50 nMol FLAG-peptide (Kodak).

The same approach was used to obtain FLAG::Hsp60. As shown in Figure 15 (lane 1), the protein is homogenous and migrates as a single band (61 kD) on SDS-PAGE.

**8. Antibodies:**

For anti-GST-LRP antibody production 1 ml of a 1:1 slurry of GST::LRP immobilized on glutathione sepharose beads or 600  $\mu$ l of soluble GST::LRP were added to 0.85% NaCl to a total volume of 2.6 ml. MPL + TDM + CWS

Adjuvant System (RIBI adjuvant) was reconstituted with 2.0 ml of these solutions. After preparation of the preimmunserum two white albino rabbits [Charles River New Zealand; ZRL:kbl (nzw)br] each were 4 fold subcutan caudal immunized with 1 ml of immobilized and soluble GST::LRP. After 28 days the animals were boosted with immobilized and soluble GST::LRP as described above. After 14 more days the rabbits were immunized a third time as described. After 11 more days the animals were bled resulting in 200 ml of blood which was consequently coagulated for 1 h at 37°C and incubated over night at 4°C. The coagulated blood was centrifuged twice for 10 min each at 9000 rpm (in a GSA-rotor) and 10500 rpm at 4°C. 75 ml of antisera were stored at -20°C. Purification of the antibody was done by binding to a protein A-sepharose column (Pierce).

Purified polyclonal anti-LBP antibody (laminin-binding protein corresponding to LRP) was kindly provided by Dr. J.R. Starkey, Montana. Polyclonal rabbit antibody directed against a peptide corresponding to a region comprising amino acids 95 to 110 of the Syrian Golden hamster prion protein was a generous gift of Dr. M. Groschup, BFAV Tübingen. Polyclonal GST antibody was delivered by Santa Cruz Biotech, USA.

Anti-EHS-laminin antibody was purchased from Sigma.

## 9. Animals:

C57BL/6 mice inoculated intracerebrally or intraperitoneally with experimental mouse scrapie (strain C506M3) or BSE (strain 4PB1) (Lasmézas et al., 1996) were sacrificed at terminal stage of the disease by cervical fracture. Different organs were immediately removed, frozen in liquid nitrogen and kept at -80°C until they were analyzed. The same procedure was applied to Syrian golden hamsters inoculated intracerebrally with scrapie strain 263K. Animals. C57BL/6 mice inoculated intracerebrally or intraperitoneally with experimental mouse scrapie (strain C506M3) or BSE (strain 4PB1)21 were sacrificed at terminal stage of the disease by cervical fracture. Different organs were immediately removed, frozen in

liquid nitrogen and kept at -80°C until they were analyzed. The same procedure was applied to Syrian golden hamsters inoculated intracerebrally with scrapie strain 263K.

**10. Preparation of tissue homogenates from Scrapie and BSE infected and uninfected animals:**

Brain (one whole hemisphere), spleen, pancreas, and pieces of liver and skeletal muscle were homogenized at 20% (w/v) in an isotonic glucose solution by means of a Ribolyser® (Hybaid). 280 µl of SDS-sample buffer were added to 40 µl of the homogenates, heated at 95° C for five minutes and centrifuged at 15000 RPM for 15 minutes. 20 µl (0.5 mg of total protein) were analyzed by western blotting.

**11. SDS PAGE and Immunoblotting:**

Protein samples were analyzed on 12.5 % SDS Phastgels (Pharmacia) run on a Phastsystem as described previously (Heukeshoven et al., 1988) or Mighty Small gels according to the manufacturer's protocol (Hoefer). Following electrophoresis, gels were blotted onto polyvinylidene difluoride membrane (PVDF) for 40 min. at 70° C in case of the phastgels or in a Semiphor Unit (Hoefer) in case of Mighty Small gels. Phastgels were stained automatically with silver in a development unit (Pharmacia) or with Coomassie Brilliant Blue as described. The blots were incubated with a polyclonal anti-LRP/anti-PrP antibody at a 1:100/1:800 dilution. The incubation steps were performed as described previously (Edenhofer et al. 1996). Antibody detection was performed by chemiluminescence (ECL system, Amersham).

**12. Laminin binding assay:**

50 µl of glutathione sepharose beads either solely or coupled with GST (1 µg; 37 pMol) or GST::LRP (2,5 µg, 37 pMol) were equilibrated with TCM buffer containing 25 mM Tris.HCl pH 7.4 at 4°C, 5 mM MgCl<sub>2</sub>, 5 mM CaCl<sub>2</sub>. After addition of Engelbreth-Holms-Swarm (EHS) laminin (Boehringer Mannheim; 3.5 µg; 17.5 pMol) in TCM buffer, reactions were carried out overnight at 4°C, beads subsequently washed four times with TCM and analyzed by Western Blotting employing an anti-laminin antibody (Sigma).

**13. Northern blot analysis:**

A 550 bp DNA probe was generated by restriction of pJG-I.91 with *Asu*II and *Eco*RI. The probe was <sup>32</sup>P-labeled using a random labeling kit (Gibco) and hybridized with a commercially available human multiple tissue Northern blot (Clontech). For controls a radiolabelled β-actin probe was hybridized. Hybridization was done with the ExpressHyb system (Clontech) at 68° C and the blot washed as recommended by the supplier. The blot was exposed for two days at -80° C with two intensifying screens.

**Example 1: Identification of LRP as a compound specifically binding to PrP by using the Yeast Two-Hybrid Screen**

Construction of pSH2-1/pEG202-GST, pSH2-1/pEG202-PrP<sup>c</sup>, pSH2-1/pEG202-GST-PrP<sup>c</sup>, pSH2-1-PrP<sup>c</sup>-GST was described in Edenhofer et al., 1996. As a bait protein we used the LexA (amino acids 1- 87) binding domain fused to GST-PrP<sup>c</sup> screening a HeLa cDNA library fused to the acidic transactivation domain B42 in the pJG4-5 as described previously (Edenhofer et al., 1996). Potential positive EGY48 transformants were selected by growth on -Ura, -His, -Trp, -Leu in the presence of galactose due to the gal-promoter of the DNA-insert in pJG4-5. Positive clones were probed for β-galactosidase production by dotting them on galactose plates supplemented with 5-bromo-4-chloro-3-indolyl-β-D-galactopyranoside (X-Gal). The

cDNAs of positive clones were recovered and transformed in *E. coli* KC8 as described (Edenhofer et al., 1996) and sequenced. For control experiments the plasmid pSH2-1, pSH2-1-GST, pSH2-1-GST::rPrP<sup>c</sup>, pSH2-1-CTF-2 (Wendler et al., 1994) and pEG202-bicoid Gyuris et al., 1993) were retransformed in EGY48 and the transformants tested for  $\beta$ -galactosidase production and their Leu<sup>+</sup>-phenotype. At least five retransformants were dotted on corresponding plates and incubated for 3 days at 30°C.

Yeast strain EGY 48 was transformed with the pSH-GST-PrP<sup>c</sup> construct coding for GST::PrP<sup>c</sup> fused to LexA and tested for intrinsic activation as described previously (Edenhofer et al., 1996). Correct expression of the bait protein GST::PrP<sup>c</sup> was confirmed by the repression activity of LexA. The control baits LexA-bicoid and LexA-Gal4 were also positive in the repression assay (data not shown). Expression of lexA-GST::PrP<sup>c</sup> with a molecular weight of approx. 53 kDa was confirmed by western blotting developed with a polyclonal PrP specific antibody (data not shown). The PrP specific antibody did not recognize any proteins in the case of pSH-GST and pSH transformed yeast cells (data not shown). *S. cerevisiae* was cotransformed with pSH-GST-PrP<sup>c</sup>, the reporter plasmid pSH18-34 and the prey plasmid pJG4-5, containing a HeLa-cDNA library controlled by a galactose-inducible promoter. A total of approximately  $6 \times 10^5$  transformants were pooled and an aliquot induced by adding galactose supplemented medium. Plating of the induced culture on Leu-deficient galactose plates resulted in approx. 2,000 colonies. 300 of them were screened for the  $\beta$ -galactosidase phenotype. The pJG4-5 plasmids of 55 clones were recovered and sequenced after retransformation in *E. coli* KC8 strain. Nine clones (corresponding to approximately 20 %) encoded N-terminal truncated forms of the 67 kDa High Affinity Laminin receptor precursor (LRP) with 43, 45, 46, 89, 130 and 156 amino acids lacking at the N-terminus. Specificity of the PrP-LRP interaction was demonstrated by several retransformation experiments. Cotransformation of pJG4-5 plasmid III.93 coding for the laminin receptor precursor (amino acids 44-295) and pSH-GST::PrP<sup>c</sup> resulted in blue-colored colonies and complementation of leucine auxotrophy (Fig. 1, row 1). Control plasmids pSH-GST encoding LexA-GST (Fig. 1, row 2) and pSH encoding LexA (Fig. 1, row 3) did not activate any of the reporter



systems. The two 'false-baits' LexA-CTF2 (Fig. 1, row 4) and LexA-bicoid (Fig. 1, row 5) were also negative in both reporter assays (Fig. 1, row 5) confirming the specificity of the PrP<sup>c</sup> laminin receptor precursor interaction in *S. cerevisiae*.

#### **Example 2: Mapping of the PrP-LRP binding site in *S. cerevisiae***

Mapping of the PrP-LRP interaction site was investigated by several retransformation experiments with the plasmids pJG4-5Δ43, pJG4-5Δ45, pJG4-5Δ46, pJG4-5Δ489, pJG4-5Δ130, pJG4-5Δ156 pJG4-5Δ179 coding for amino terminal truncated versions of the laminin receptor precursor lacking 43, 45, 46, 89, 130, 156 amino acids (containing 23 amino acids not homologous to the laminin receptor precursor) and 179 amino acids (lacking the laminin binding domain) at the amino terminus. pJG4-5Δ43 to pJG4-5Δ156 were isolated from the two-hybrid screen described above. pJG4-5Δ179 was constructed by partial digestion of pJG-I.91 with *Ava*I followed by an *Eco*RI digestion. The resulting approx. 7 kb DNA fragment lacking the 420 bp *Eco*RI (5') - *Ava*I (3') DNA fragment was blunted and religated resulting in pJG4-5Δ179.

The N-terminally truncated versions of the receptor LRPΔ43 to LRPΔ156 resulted in blue colored colonies (Fig. 2, rows 1-6). Transformation of LRPΔ179, however, led to a negative X-gal phenotype (Fig. 2, row 7) demonstrating that laminin and PrP<sup>c</sup> share the same binding site on LRP (amino acid 161 to amino acid 180).

#### **Example 3: Recombinant LRP synthesized in insect cells binds to Engelbreth-Holm-Swarm (EHS) laminin.**

GST::LRP isolated from AcSG2T::LRP infected Sf9 cells (Fig. 3 A, lane 2) migrates with a molecular weight of 67 kDa which was expected from the 27 kDa of GST (Weiss et al., 1995; 1996) plus 37 kDa observed from recombinant LRP expressed in highly aggressive cancer cells (Yow et al., 1988; Rao et al., 1989). No secretion of GST::LRP was observed (Fig. 3 A, lane 1), despite the fact that the *autographica californica* gp67 signal sequence (Whitford et al., 1989) was constructed at the

amino terminus of the fusion protein. A polyclonal LRP specific antibody specifically recognized the laminin receptor precursor fused to GST (Fig.3 B, lane 2) demonstrating that the recombinant LRP was immunologically active. To further prove the binding ability of the recombinant laminin receptor precursor to laminin immobilized GST::LRP was incubated in the presence of laminin from Engelbreth-Holm-Swarm (EHS) tumors. Laminin consists of two polypeptide chains B1 and B2 (each 220 kDa, Fig. 3 C, lane 4), linked via disulfide bonds to form together with polypeptide chain A (440 kDa, Fig. 4, lane 4) the characteristic asymmetric cross-structure. Binding of laminin can be detected in the presence of an anti-EHS-laminin antibody only with immobilized GST::LRP (Fig. 3 C, lane 3). No binding takes place in the presence of immobilized GST (Fig.3 C lane 2) or unloaded beads (Fig.3 C, lane 1).

#### **Example 4: LRP mRNA is present in several human organs including the brain**

To identify mRNA encoding for the human LRP in various tissues a human multiple tissue Northern blot has been screened with a DNA probe complementary to a region encoding for the laminin receptor precursor. Hybridization of the labeled fragment to the human multiple tissue mRNA blot reveals that mRNA encoding for LRP is ubiquitous distributed in heart (Fig. 4A, lane 1), placenta (lane 3), lung (lane 4), liver (lane 5), skeletal muscle (lane 6), pancreas (lane 8) and the brain (lane 2). In contrast, LRP-mRNA level in kidney was very weak (lane 7).

#### **Example 5: LRP is overexpressed in ScN2a cells**

Western Blot analysis of crude lysates with the LRP-specific antibody from Dr. Starkey (see 8., above) revealed that the 67 kDa LRP is present in the crude lysates of N2a cells (Fig. 4B, lane 2) but is overexpressed in Scrapie infected N2a cells (ScN2a) (Fig.4B, lane 3). The authentic LRP reveals the same molecular weight as recombinant GST::LRP (Fig. 4B, lane 1) from insect cells due to 27 kDa for PrP and 37 kDa for recombinant PrP. The presence of LRP in ScN2a cells favors the hypothesis discussed above that the receptor is involved in Scrapie propagation.

Moreover, LRP expression is tissue-dependent; see Table 1, above, and Figures 16 and 17.

To investigate the pathogenic relevance of the PrP/LRP interaction, LRP levels in Scrapie infected and uninfected murine neuroblastoma cells were analyzed with an LRP-specific antibody prepared as described in 8., above. Fig. 4c(a) demonstrates that the LRP level was twofold increased in Scrapie infected N<sub>2</sub>a cells (lane 2) compared to uninfected N<sub>2</sub>a cells (lane 1). The intensities of the protein bands were determined by optical scanning methods. The level of  $\beta$ -actin (42 kDa; control) remained stable in ScN<sub>2</sub>a (Fig. 4c(b), lane 3) compared to N<sub>2</sub>a cells (Fig. 4c(b), lane 2). The increased level of LRP in ScN<sub>2</sub>a cells favors the hypothesis that the LRP is involved in scrapie pathogenesis.

Furthermore, LRP protein levels in brain and spleen of terminal C57BL/6 mice intracerebrally inoculated with either a scrapie (C506M3) or a BSE (4PB1) strain were investigated. The LRP level was twofold increased in brain and spleen of scrapie infected mice (Fig. 16a, lanes 2 and 4, respectively) compared to uninfected mice (lanes 3 and 5, respectively), whereas no significant alteration of the LRP amount was observed in either organ of BSE infected mice (Fig. 16a, lanes 6, 7, 8 and 9, respectively). Levels of  $\beta$ -actin (42 kDa) were not altered in scrapie /BSE infected animals (Fig. 16b). PrP<sup>Sc</sup> accumulation is fourfold higher in the mouse scrapie model as compared to the mouse BSE model. Thus, the LRP concentration seems to correlate with the extent of PrP<sup>Sc</sup> accumulation. This was further supported by the fact that no increased LRP concentrations were observed in brain and spleen of intraperitoneally inoculated scrapie mice which display only 50 % of the PrP<sup>Sc</sup> accumulation observed in intracerebrally inoculated mice.

In order to confirm the direct correlation between LRP levels and PrP<sup>Sc</sup> accumulation, we investigated the amounts of LRP in different organs of syrian hamsters inoculated with the 263K scrapie strain, which is a model with high levels of intracerebral PrP<sup>Sc</sup> accumulation. The LRP level was fivefold increased in the brain (Fig. 17a, lane 2) and fourfold raised in the pancreas (lane 6) of scrapie infected hamsters compared to uninfected control hamsters (lanes 3 and 7, respectively). LRP is weakly expressed in the spleen (lane 5) and its level only marginally (1.5 fold) increased in

this organ in scrapie infected hamsters (lane 4). These data fit with the high neuroinvasiveness of the 263K strain where PrP<sup>Sc</sup> and infectivity are extremely high in the brain and, in contrast, low in the spleen. The pancreas exhibits PrP<sup>Sc</sup> and pathological changes particularly located in the islets of Langerhans, although its role in the pathogenesis of prion diseases is poorly understood.

In contrast, LRP expression failed in skeletal muscle (lanes 10 and 11) and was unaltered in the liver of scrapie infected hamsters (lane 8) compared to uninfected hamsters (lane 9).  $\beta$ -actin or actin (42 kDa) levels, respectively, were unaltered in brain, spleen, pancreas, liver and skeletal muscle of scrapie infected compared to uninfected hamsters (Fig. 17b).

In summary, LRP levels are increased only in those organs that exhibit infectivity and PrP<sup>Sc</sup> accumulation such as brain, spleen and pancreas (see Table 1, below).

**Table 1** Increase of LRP levels in Scrapie/BSE infected versus uninfected cells and tissues\*

MOUSE	brain	spleen	ScN <sub>2</sub> a/ N <sub>2</sub> a cells		
Scrapie infected	2 fold	2 fold	2 fold		
BSE infected	1.1 fold	unchanged			
HAMSTER	brain	spleen	pancreas	liver	skeletal muscle
Scrapie infected	5 fold	1.5 fold	4 fold	unchanged	not expressed

\*values have been calculated by optical scanning methods.

**Example 6:** rPrP23-231 (rPrP<sup>c</sup>) and rPrP90-231 (rPrP27-30) interact with LRP in insect cells co-infected with recombinant baculoviruses

FLAG tagged PrP<sup>c</sup> (Fig. 5A, lane 1) and FLAG::rPrP90-231 (Fig. 5A, lane 2) secreted from Baculovirus infected insect cells revealed molecular weights of 27 kDa and 17 kDa, respectively. Co-infection assays demonstrate that GST::LRP can only be detected by co-infecting AcSG2T::LRP with FLAG-BAC::rPrP23-231 (Fig. 5B, lane 3) or FLAG::BAC::rPrP90-231 (Fig. 5B, lane 1). No interaction takes place when AcSG2T expressing GST was co-infected with FLAG-BAC::rPrP23-231 (Fig. 5B, lane 2) or FLAG::BAC::rPrP90-231 (Fig. 5B, lane 4). As an additional control GST::LRP failed to interact with Src kinase p59<sup>hck</sup> (Danhauser-Riedl et al., 1996) fused to GST (data not shown) demonstrating the specific interaction of rPrP23-231 and rPrP90-231 with LRP in insect cells.

#### **Example 7: rPrP23-231 (rPrP<sup>c</sup>) interact with authentic LRP in Cos-7 cells**

To further confirm the LRP/PrP interaction in mammalian cells, we co-transfected Cos-7 cells with plasmids encoding for authentic LRP and PrP<sup>c</sup>. Recombinant LRP recognized by a LRP specific antibody revealed a molecular weight of 37 kDa (Fig. 6B, lane 3) as expected from the gene product expressed from LRP-cDNA (Yow et al., 1988). FLAG::haPrP23-231 was synthesized as a 27 kDa protein (Fig. 6A, lane 1) and recognized by a PrP specific antibody. Co-transfection assays with LRP and rPrP23-231 proved the presence of LRP only after simultaneous expression of both proteins (Fig. 6B, lane 2). In the absence of pcDNA3-LRP no interaction takes place (lane 1). In summary the interaction of the 67 kDa laminin receptor precursor with prion proteins was demonstrated in the yeast, in insect and mammalian cells.

#### **Example 8: LRP knock-out mice are resistant to PrP<sup>Sc</sup> infection**

The function of LRP as a receptor for PrP<sup>Sc</sup> can be assayed by employing LRP knock-out mice. Because LRP belongs to a multicopy gene family (Bignon et al., 1991; Douville and Carbonetto, 1992; Fernandez et al., 1991), it is impossible to use the classical knock-out strategy recently described for the construction of a *bir1*-knock-out mouse (Förster et al., 1996). Thus, it is necessary to switch off additional

loci. This can be done by connecting the classical knock-out approach with an antisense strategy. This procedure leads to mice with one disrupted LRP gene. The mRNA of further active LRP genes can be inactivated by the induced antisense mRNA.

The first step in the generation of a LRP knock-out mouse is the screening of one homologue of the LRP gene in a genomic mouse library (129 SV) cloned in a  $\lambda$ -FixII™ vector. Employing an LRP specific DNA probe leads to the identification of the genomic structure of the LRP gene, which is subcloned, mapped and sequenced. The second step includes the construction of a replacement vector (Fig. 11). Parts of the LRP gene are disrupted and replaced by the gene encoding neomycin resistance for positive selection (Fig. 11) adjacent to an anti-LRP cassette containing the antisense LRP sequence under the control of an inducible promoter such as the metallothionine promoter or tetracycline-responsive promoter (Gossen and Bujard, 1992). The thymidine kinase gene flanking the homology regions on either side of the LRP gene enables negative selection. The replacement vector is transferred to murine embryonic stem cells (ES) via electroporation (Fig. 12A). The presence of G 418 and gancyclovir leads to clones potentially harboring the homologous recombination event. Screening of positive selected clones via PCR and Southern blot analysis allows the identification of clones mutated in one LRP gene on one allele (Fig. 11, 12A).

Homologous recombined ES cell clones are transferred into embryonic morulas or blastocytes by morula aggregation and blastocyst injection. Chimeras are identified by coat color and tested for germ line integration by Agouti-coat color (to identify the integration of the homologous recombined embryonic stem cells) and Southern blotting. Heterozygous mice are intercrossed to produce homozygous LRP<sup>-/-</sup> mice with one disrupted LRP gene. In order to inactivate the additional LRP genes, the metallothionine or tetracycline-responsive promoter (Gossen and Bujard, 1992) is activated by feeding the mice with Zinc or tetracycline, respectively. The antisense LRP mRNA binds additional generated LRP mRNA. This approach can be done during different developmental stages and can be proven by Northern blot analysis, Western blotting and FACS analysis.

### Characterization of the phenotype of the LRP<sup>-/-</sup> mice

The phenotype of the LRP<sup>-/-</sup> mice can be characterized including behaviours, histological examination of the brain and other organs and neurological investigations.

#### Phenotypic characterization

The mice are monitored over their whole lifespan for the occurrence of clinical abnormalities including neurological signs. In addition, to evaluate the motor coordination of the mice objectively, their performance is tested on a rotorod. With respect to the behavioural characterization, the learning ability of the LRP<sup>-/-</sup> mice can be assessed and compared with WT mice possessing the same genetic background, by means of appropriate tests (e.g. swimming navigation and Y-maze discrimination test).

Anatomical investigations are made to detect gross abnormalities of the brain and other organs; histological examinations are performed using classical techniques and haematoxylin-eosin staining.

The crucial experiment, however, is the inoculation of the LRP<sup>-/-</sup> mice with PrP<sup>Sc</sup>-enriched infectious fractions from mouse and cattle.

PrP<sup>Sc</sup> detection procedure (Lasmezas et al., 1997). Mice infected with PrP<sup>Sc</sup> are sacrificed at the pre-mortem stage by cervical fracture, and brains are immediately removed. One hemisphere (including the cerebellum) is frozen in liquid nitrogen, and stored at -80°C for PrP analysis. The other hemisphere is fixed for pathological examination. For PrP<sup>Sc</sup> purification, the whole brain hemisphere is homogenized to 10% (w/v) in a 5% glucose solution. Briefly, proteinase K (PK) is used at 10 µg/ml and digestion is blocked with PMSF. After addition of sarkosyl to 10% and Tris.HCL pH 7.4 to 10 mM, samples are incubated for 15 minutes at room temperature. They are then centrifuged at 245000 g for 4 hours at 20°C on a 10% sucrose cushion (Beckmann TL100 ultracentrifuge). Pellets are resuspended in Laemmli buffer and analyzed by Western blotting employing a polyclonal anti-mouse PrP antibody. The inoculation of the LRP<sup>-/-</sup> mice with PrP<sup>Sc</sup> shows that the mice are resistant towards PrP<sup>Sc</sup> infection.

## **Example 9: Inactivation of the LRP genes in neuroblastoma cells (N<sub>2</sub>a) by Antisense RNA technique**

### **(a) Introduction**

LRP expression can be downregulated in the presence of an antisense LRP mRNA. An alternative ribozyme approach is also conceivable.

First, the downregulation of LRP can be measured in cell culture systems employing scrapie infected versus uninfected neuroblastoma cells (N<sub>2</sub>a). Scrapie infected N<sub>2</sub>a cells should lose their infectivity in the presence of the antisense/ribozyme construct and neuroblastoma cells should not be infectable with PrP<sup>Sc</sup> any more in the presence of antisense LRP mRNA/ribozymal RNA.

Second, the same transfection vector can be microinjected into oocytes (fertilized eggs). After microinjection, survived eggs can be transferred into the oviduct of a pseudopregnant foster mother. The offsprings should show decreased levels of LRP or should fail to express LRP any more resulting in a complete resistance towards a scrapie infection.

Two examples for an antisense and an ribozyme derived approach are given below. Microinjection of in vitro transcribed RNA and antisense oligonucleotides in mouse oocytes and early embryos have been performed to study the gain and loss-of-function of genes (Kola and Sumarsono, 1996). An adenoviral VAI small RNA has been used as a carrier for cytoplasmic delivery of ribozymes (Prislei et al., 1997).

### **(b) Methodology**

#### **Construction of antisense LRP expression vector pCI-neo-asLRP**

A construct spanning the cDNA from position -65 to +901 of the mouse 37 kDa LRP ORF was generated by RT-PCR from total RNA isolated from N<sub>2</sub>a neuroblastoma cells using two oligonucleotide primers. The resulting 970 bp DNA fragment was subcloned in antisense orientation into the pCI-neo mammalian expression vector



(Promega) using *NheI* (5') and *SmaI* (3') restriction sites. The correct insert was verified by restriction analysis and dideoxy sequencing.

### **Cell Culture and Transfection**

Scrapie-infected (ScN2a) and non-infected mouse neuroblastoma cells (N2a) were maintained in Dulbecco's modified Eagle's medium (DMEM) (Sigma) supplemented with 10 % FCS, 1 % Glutamine, 100 µg/ml penicillin and 100 µg/ml streptomycin. Cells were grown in a 25 cm<sup>2</sup> culture bottle to 70 % confluency under the above conditions and transfected in serum-free medium for 14 hours with 100 µg of Lipofectamine (Life Technologies) and 16 µg of plasmid DNA pCI-neo-asLRP. After 48 hours the medium was replenished with medium containing 400 µg/ml G418. (Life Technologies). Colonies resistant to G418 were expanded and screened for antisense LRP expression by Northern blot analysis. Furthermore LRP levels were determined by SDS-PAGE and Western-Blotting.

### **Microinjection into mouse oocytes**

#### **Restriction hydrolysis of pCI-neo-asLRP**

Prior to microinjection in oocytes bacterial DNA-sequences had to be removed from the pCI-neo-asLRP plasmid. Therefore the plasmid was cleaved upstream the CMV promoter and downstream the Neomycin gene with *BglII* and *BamHI*, respectively. The DNA-fragment was purified by TAE-buffered gel electrophoresis and eluted from the gel by standard procedures. After phenol extraction and ethanol precipitation the DNA was resuspended in TE-buffer (5 mM TrisHCl, pH 7.4, 0.2 mM EDTA, pH 7.4), filtered through a 0.2 µm filter and the DNA concentration determined. The DNA was diluted in TE-buffer to a concentration of 3 to 5 ng/ml and 20 µl aliquots were stored frozen until use.

### **Superovulation and mating**

Superovulation in female B6D2F<sub>1</sub> mice was induced by intraperitoneal injection of 8 IU (International Units) of PMSG (pregnant mare's serum gonadotropin). After 48 hours 7 IU of hCG (human chorionic gonadotropin) were injected intraperitoneally. Female mice were subsequently brought together with stud males of the same strain for mating. Animals were kept together overnight.

After 24 hours successful mating was verified by taking a plug control. After that female mice were killed and tubes prepared. Fertilized eggs in cumulus cells were washed out and were treated with hyaluronidase for removal of the cumulus cells. Fertilized eggs were kept in culture medium.

#### **Microinjection of DNA in oocytes**

The isolated restriction fragment (as described above) was injected into the pronuclei of the fertilized mouse eggs using a micromanipulator. 3-5 ng of DNA were injected into 90-240 fertilized eggs. After microinjection survived eggs were transferred into the oviduct of a pseudopregnant foster mother.

Offsprings (the presence of the antisense/ribozyme cassette will be analyzed by PCR) should express antisense LRP RNA and should show decreased levels of LRP or should fail to express LRP completely. These animals should be partially or totally resistant towards a Scrapie infection.

#### **Example 10: Localization of LRP and PrP on the surface of neuroblastoma cells**

Scrapie infected and non-infected N<sub>2</sub>a mouse neuroblastoma cells and human osteosarcoma (HOS) cells were maintained as monolayer cultures in DMEM medium (Gibco) supplemented with 10 % FCS, 1 % Glutamine, 100 µg/ml penicillin and 100 µg/ml streptomycin. Cells were seeded half confluent on 10 mm diameter coverslips and were grown overnight for attachment. Cells were fixed with 4 % paraformaldehyd in phosphate-buffered saline (PBS) for 20 minutes at 4 °C. Fixed

cells were washed three times in PBS. For cytoplasmic staining cells were permeabilized with 0.1 % Triton X-100 in PBS for 10 min at 4 °C. After rinsing three times with PBS coverslips were blocked with 10 % FCS in PBS for one hour at room temperature and washed once in PBS. For detection of LRP cells were incubated for one hour at room temperature with a monoclonal LRP-specific antibody, diluted 1:200 in 10 % FCS in PBS. Controls were incubated with pre-immuneserum in 10 % FCS in PBS. Afterwards cells were rinsed three times in PBS and a fluorescein isothiocyanate (FITC)-conjugated anti-mouse secondary antibody (Jackson ImmunoResearch Lab.) diluted 1:100 in 10 % FCS in PBS was applied for 45 minutes at room temperature. Coverslips were then washed three times with PBS and mounted in Mounting Medium (Sigma). Cells have been visualized in a immunofluorescence microscope. Magnification was from 400 fold to 630 fold.

Cultivated Murine Neuroblastoma cells (N<sub>2</sub>a, Figure 18) and human osteosarcoma cells (HOS) have been incubated with a LRP specific antibody, followed by the use of a second FITC conjugated anti-mouse secondary antibody. The dense circle on the surface of the cells indicate that LRP is on the surface of neuronal cells. PrP<sup>c</sup> appears also on the surface of the neuronal (or other Scrapie infectable) cell anchored by glycosylphosphatidyl inositol (GPI) (Rogers et al., 1991). Although treatment of the cells with phospholipase c (PIPL-c) removes PrP<sup>c</sup> from the cell surface by cleaving off its GPI anchor (Caughey and Raymond, 1991), some researchers have evidence that a transmembrane region (TM) of PrP<sup>c</sup> exists (Harris and Lehmann, 1996) which is responsible for fixing a mutant PrP on the cell surface. Thus, LRP and PrP are both localized on the surface of Scrapie infectable cells.

**Example 11: Uptake of recombinant PrP from human and cattle by murine neuroblastoma cells (N<sub>2</sub>a)**

For incubation experiments with recombinant prion proteins cells were incubated overnight with 3 µg of recombinant GST::huPrP, GST::bovPrP and GST per ml of culture medium. For inhibition studies cells were pre-incubated for two hours with a LRP-specific antibody diluted 1:100 in culture medium. After incubation overnight

cells were fixed, permeabilized and immunostained as described above. For detection of recombinant proteins a polyclonal anti-GST (Santa Cruz Biotechnologies) or anti-PrP 3B5 primary antibody (1:100 dilution in 10 % FCS in PBS) was used. As a secondary antibody either a Texas Red or FITC-conjugated anti-rabbit antibody (Jackson ImmunoResearch) was used.

Figure 19 (left panel) demonstrates the uptake of bovine PrP fused to GST by N<sub>2</sub>a cells. The small dots represent the bovine PrP on the surface of N<sub>2</sub>a cells detected by a PrP specific antibody (3B5). The uptake was prohibited when the cells have been preincubated with a LRP specific antibody (Rieger et al., 1997) (Figure 19, right panel) demonstrating that LRP is responsible for the uptake of the prion protein by N<sub>2</sub>a cells. Thus, the LRP specific antibody can be used as a therapeutic tool to prevent the uptake of the prion protein PrP by the LRP.

The same result has been obtained when the human prion protein was used. GST alone failed to bind to the cells demonstrating that the PrP portion of the GST::PrP fusion protein is responsible for the uptake by N<sub>2</sub>a cells.

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**CLAIMS**

1. A pharmaceutical composition comprising a soluble laminin receptor precursor (LRP), a mutein, fused protein, salt, functional derivative or fragment thereof that can bind to PrP<sup>Sc</sup>, PrP<sup>C</sup> or fragments thereof and, optionally, a suitable diluent, carrier and/or excipient.
2. A pharmaceutical composition comprising a compound that blocks the interaction of LRP and PrP<sup>Sc</sup>, PrP<sup>C</sup> or fragments thereof and, optionally, a suitable diluent, carrier and/or excipient.
3. An antibody or a fragment thereof or a nucleic acid that binds to PrP<sup>Sc</sup>, PrP<sup>C</sup>, LRP or fragments thereof.
4. A pharmaceutical composition comprising one of the compounds of claim 3.
5. A pharmaceutical composition comprising an antisense-RNA or ribozyme which reduces or inhibits the expression of LRP.
6. The pharmaceutical composition of any one of claims 1, 2, 4 or 5 for treating a disease related to the presence of PrP<sup>Sc</sup>.
7. The pharmaceutical composition of claim 6, wherein the disease is transmissible spongiform encephalopathy.
8. The pharmaceutical composition of claim 7, wherein the transmissible spongiform encephalopathy is scrapie, bovine spongiform encephalopathy, Creutzfeldt-Jakob disease, Fatal Familial insomnia, chronic wasting disease or feline spongiform encephalopathy (FSE).

9. Use of the compound defined in any one of claims 1 to 5 for the preparation of a pharmaceutical composition.
10. Use according to claim 9 for the preparation of a pharmaceutical composition for the treatment of diseases as defined in any one of claims 6 to 8.
11. Expression vector pFLAG-BAC having the nucleic acid sequence shown in Figure 14 or substantially said sequence.
12. The vector of claim 11 further containing the rPrP23-231 cassette (648 bp) excised from pAcSG2T::rPrP<sup>c</sup>23-231 via BamHI and EcoRI at the 5'- and 3' end as an insert in the polylinker sequence.
13. The vector of claim 11 further containing the rPrP90-231 cassette (447 bp) excised from pACSG2T::rPrP27-30 via BamHI and EcoRI at the 5'- and 3' end as insert in the polylinker sequence.



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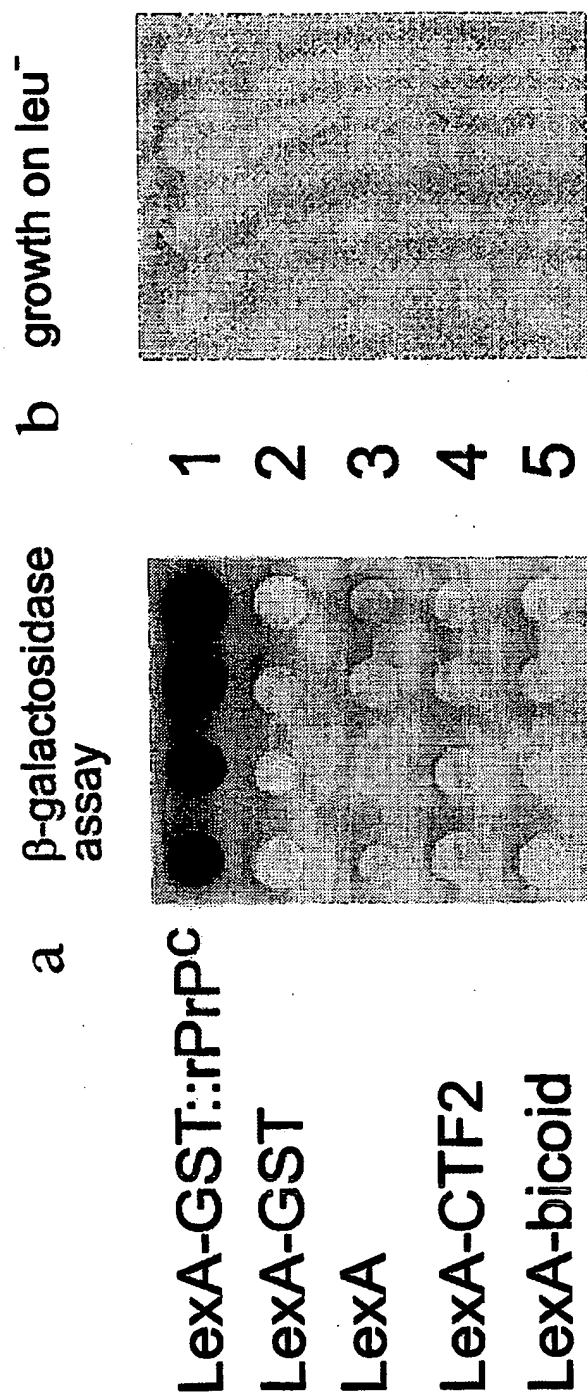


FIGURE 1

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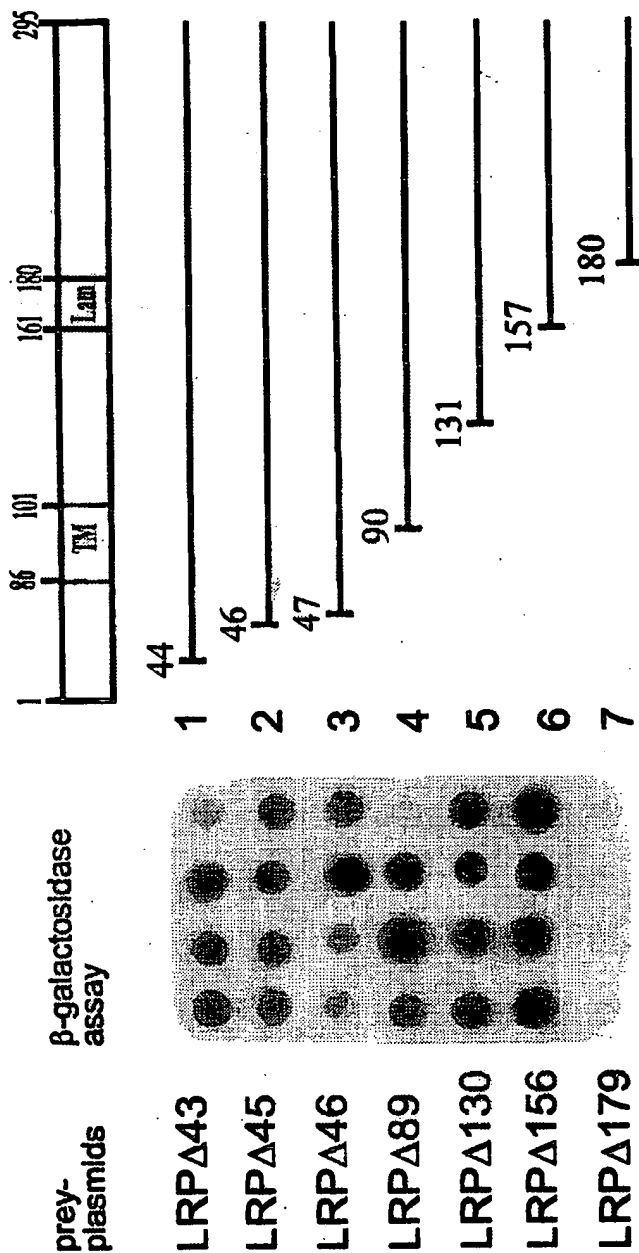


FIGURE 2

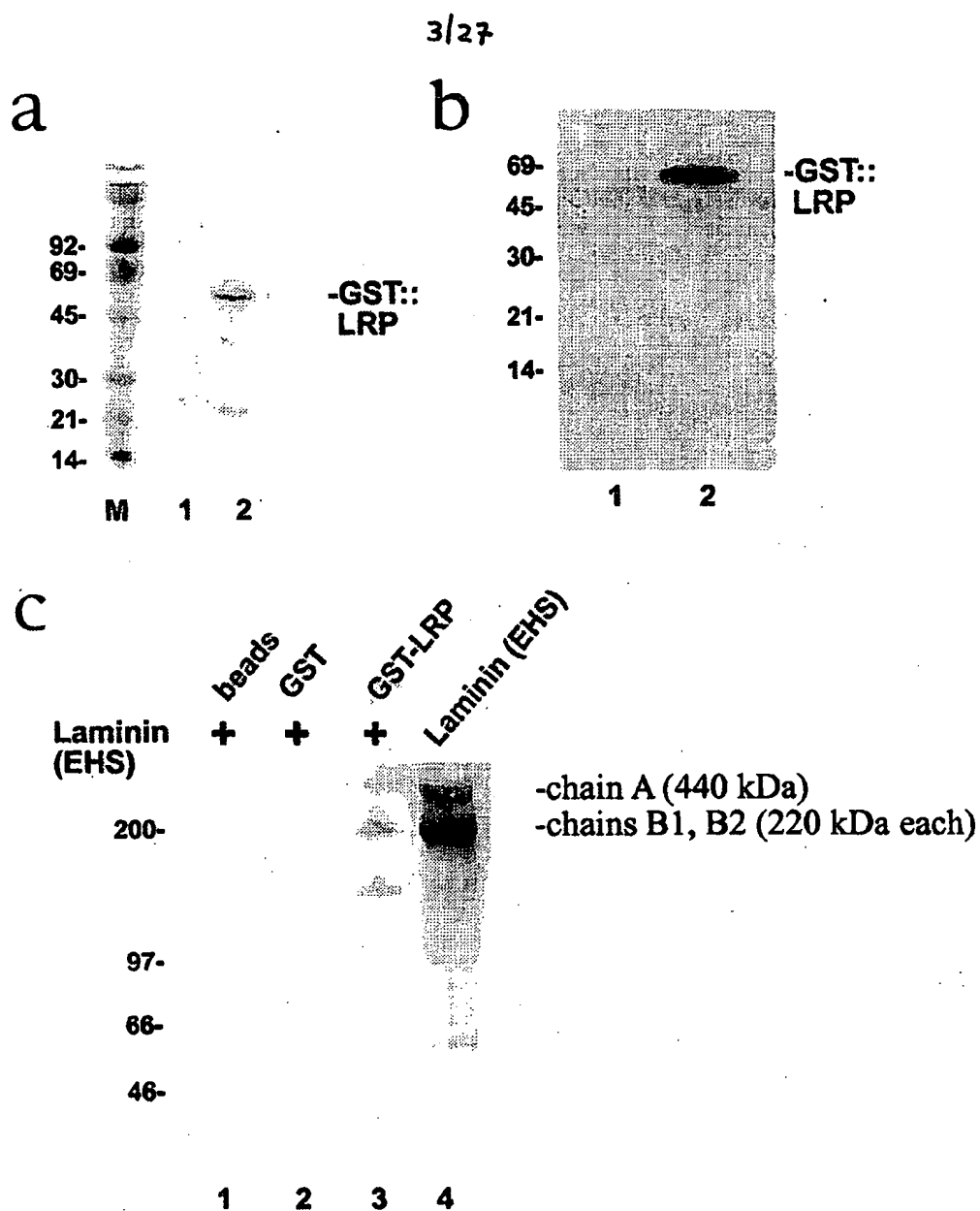


FIGURE 3

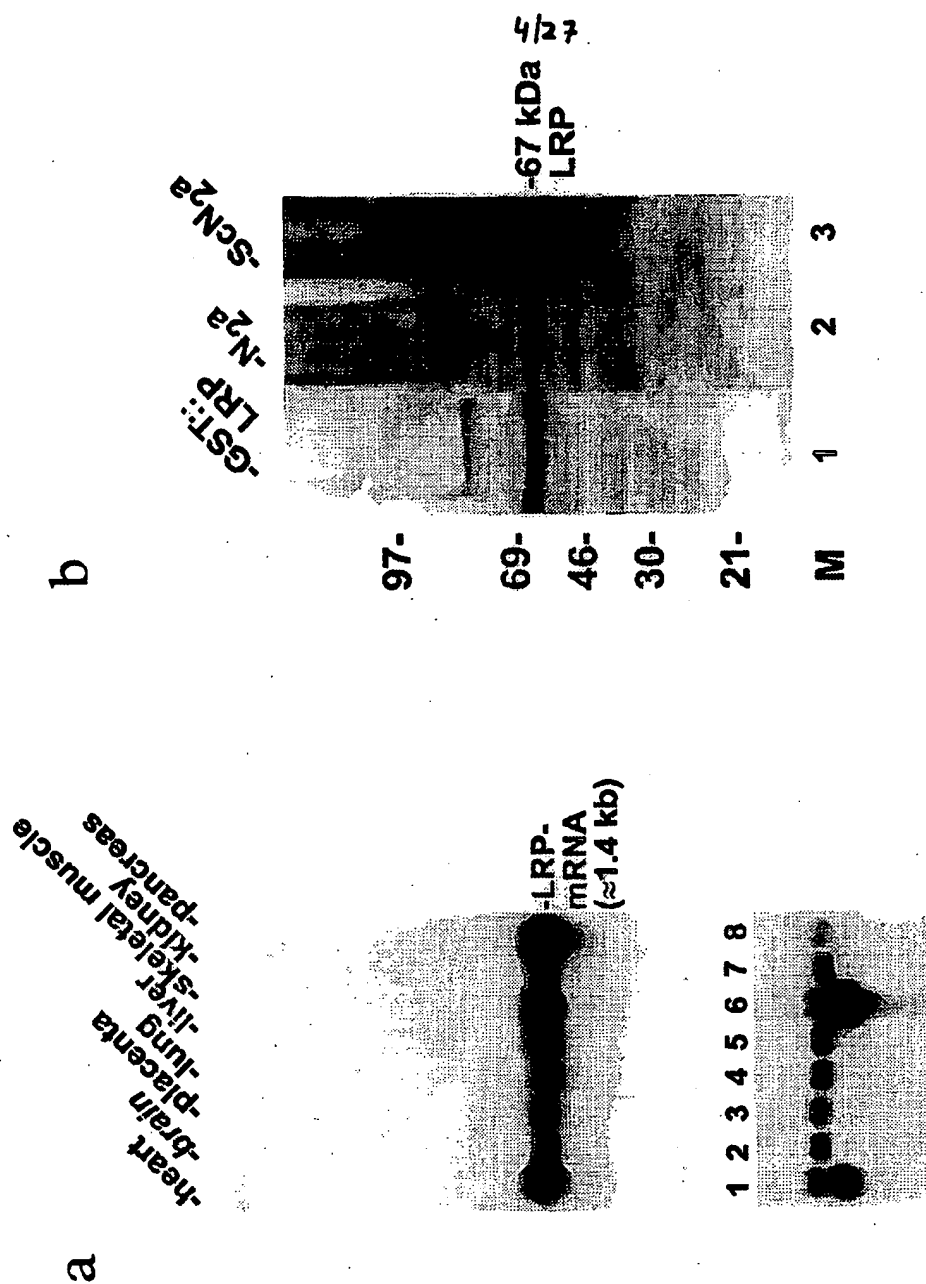


FIGURE 4

LRP levels in Scrapie infected versus uninfected N<sub>2</sub>a cells analyzed by Western Blotting

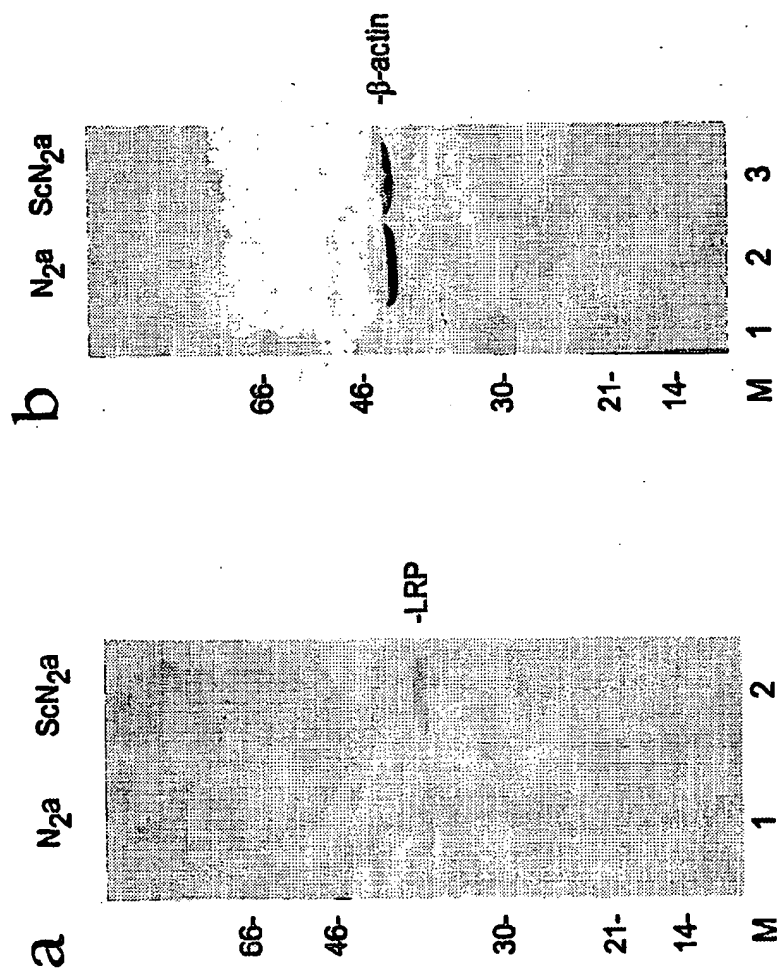


FIGURE 4 C

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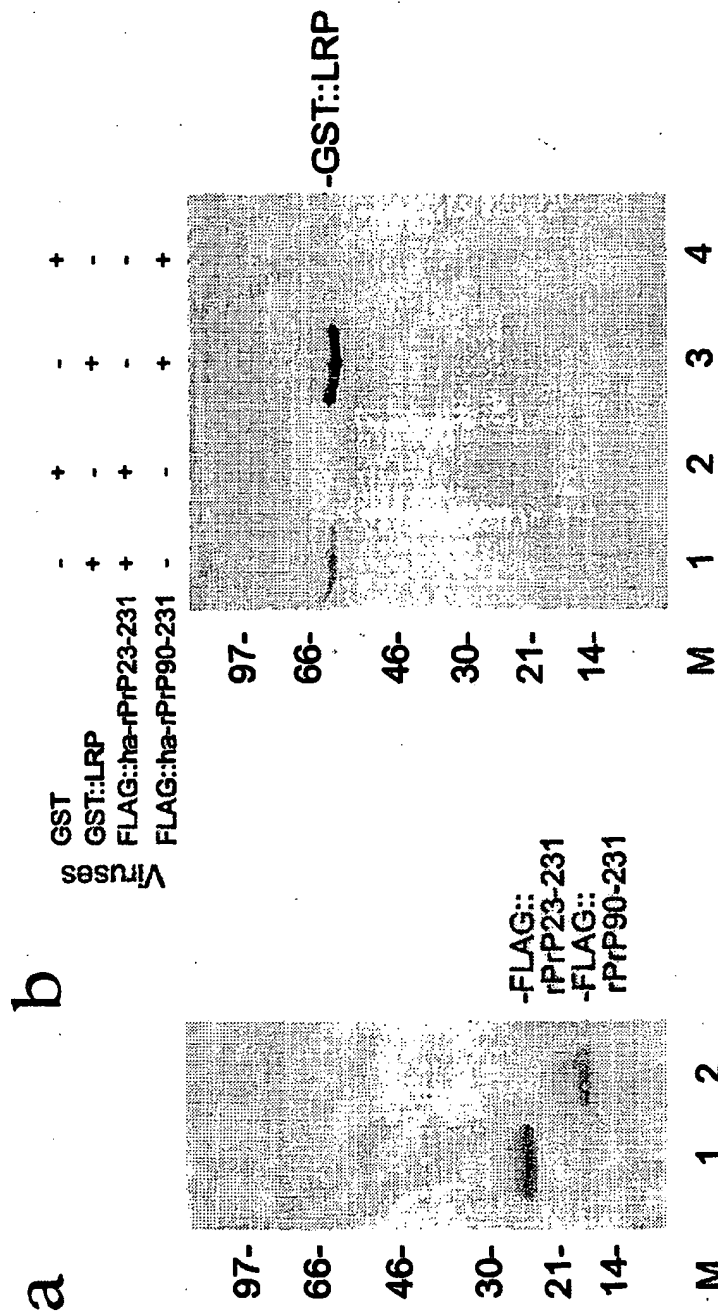


FIGURE 5

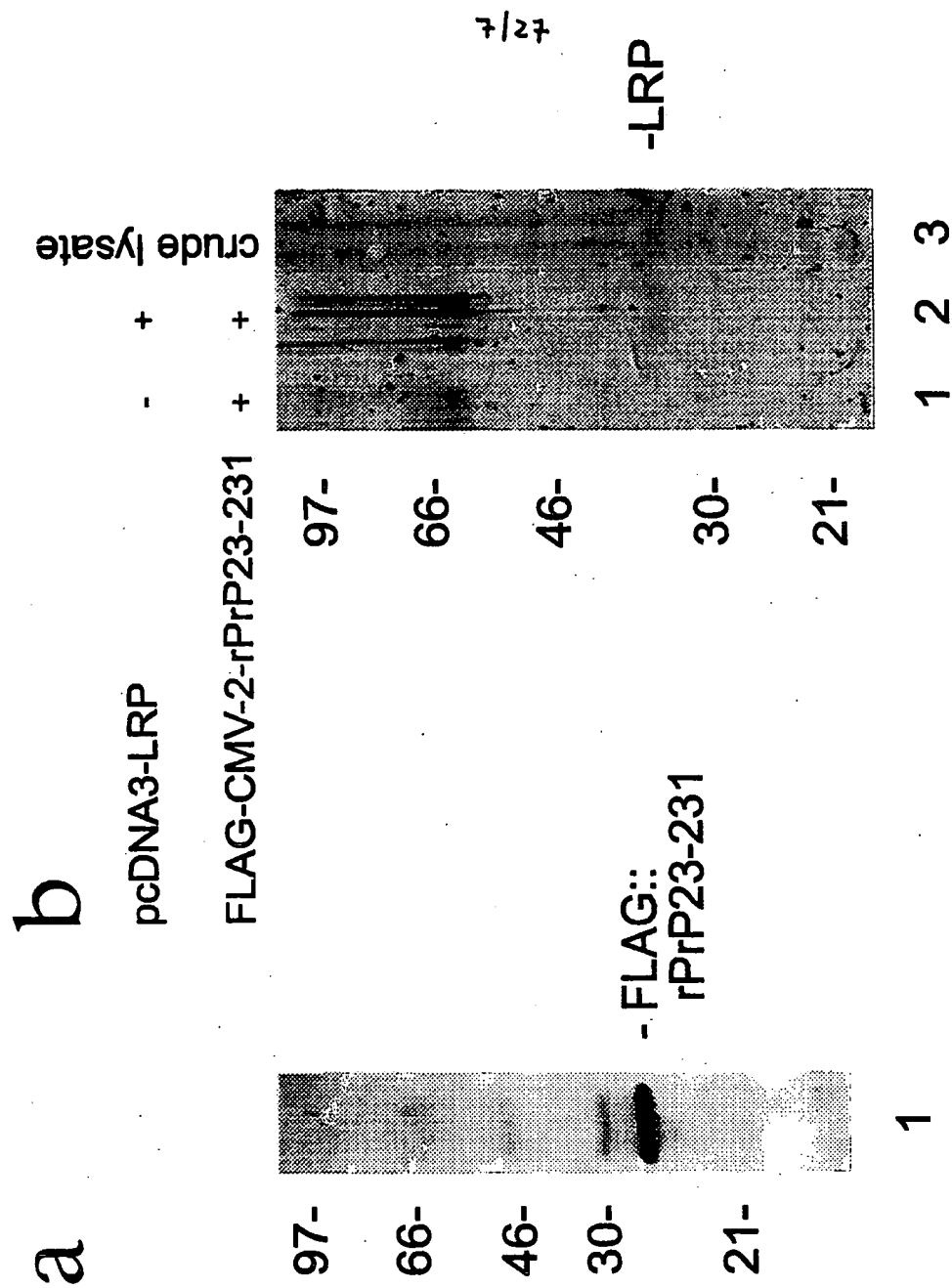
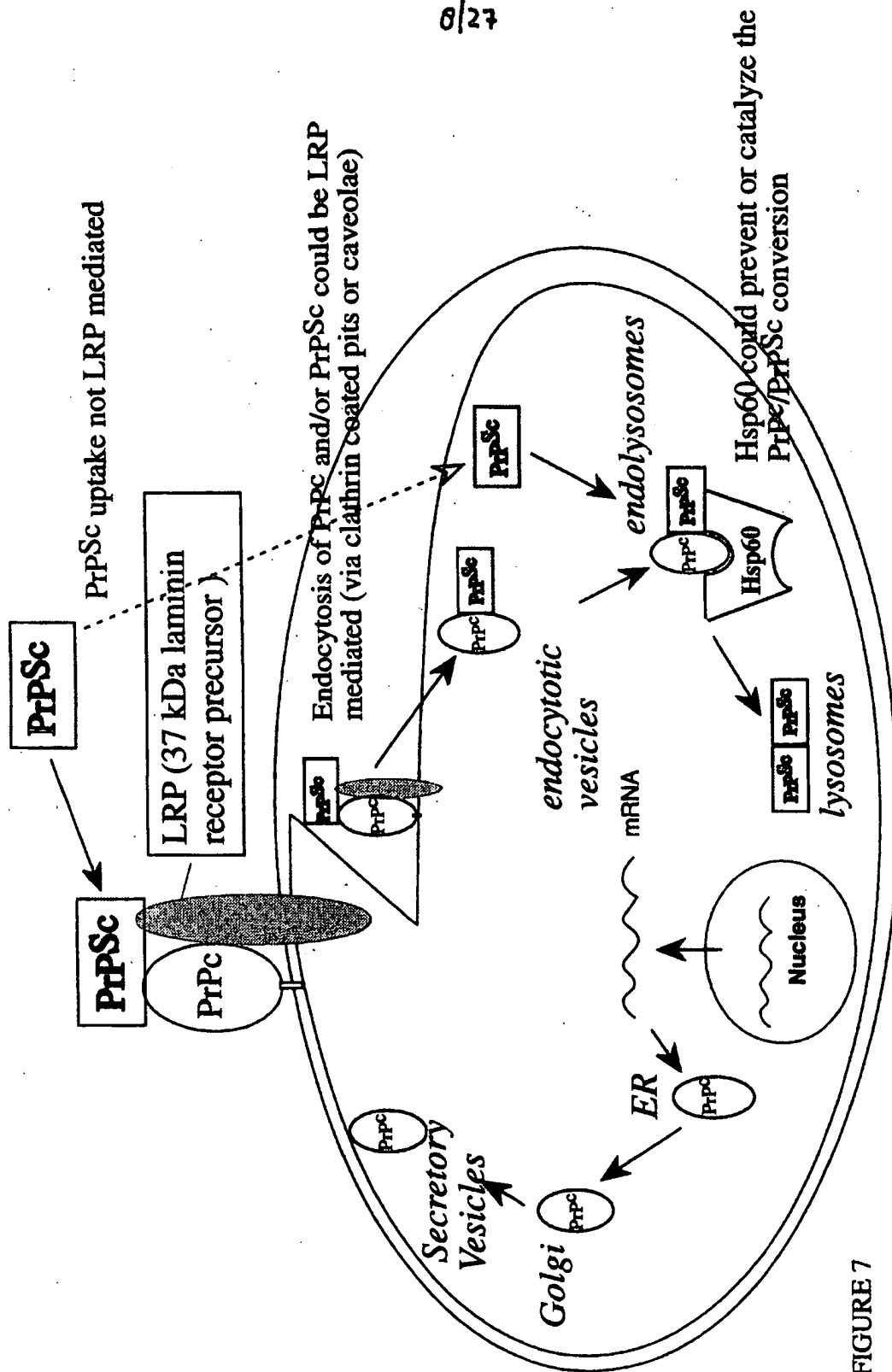


FIGURE 6

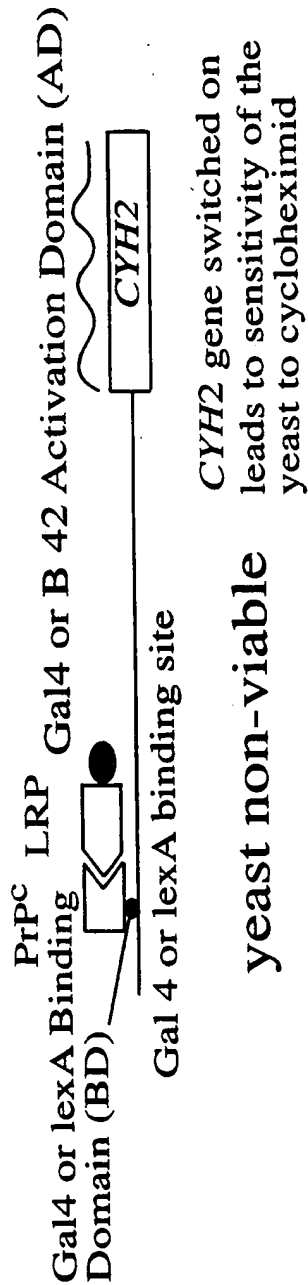
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### A Interaction between PrPc and LRP



### B No Interaction between PrPc and LRP

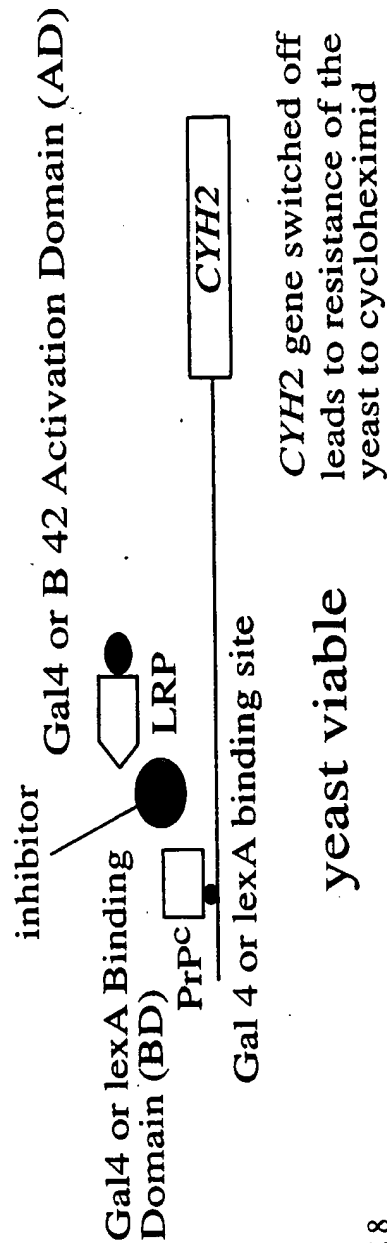


FIGURE 8

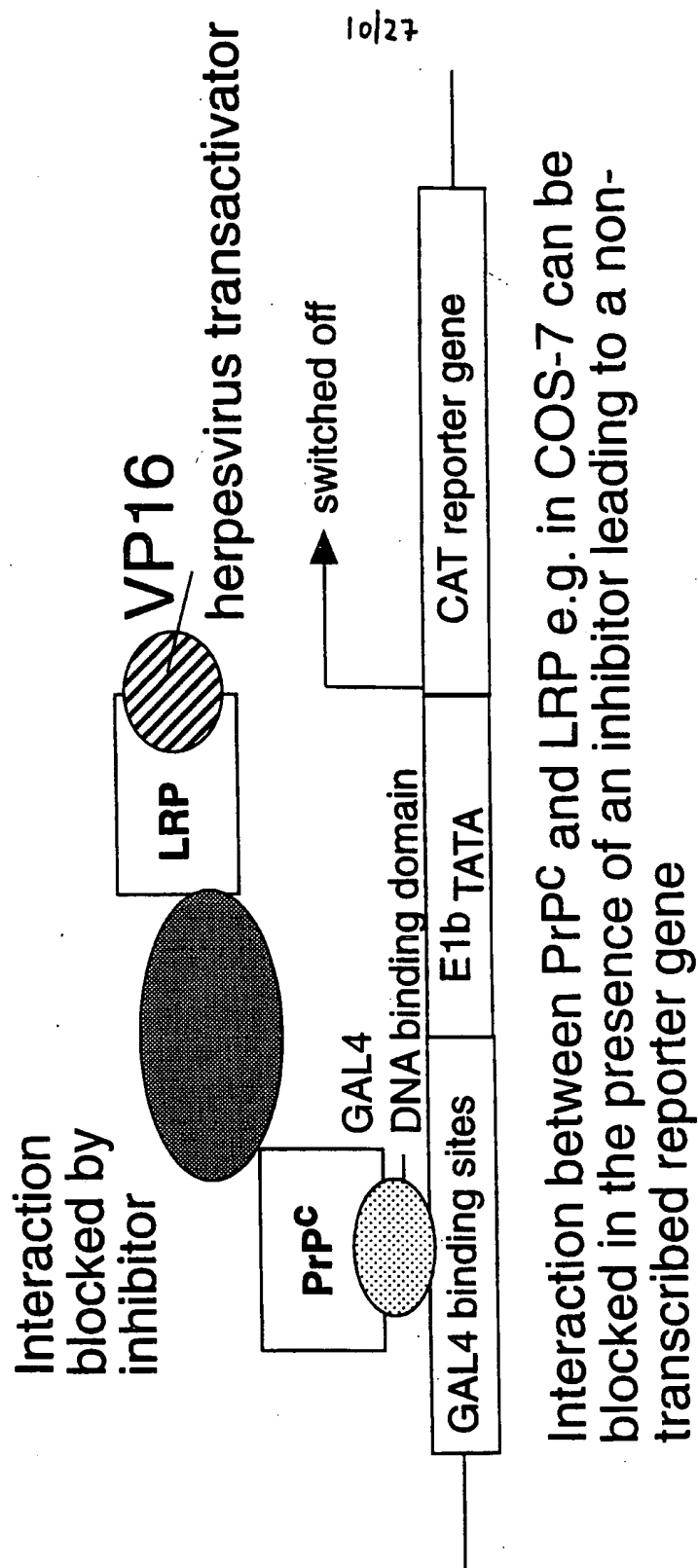


FIGURE 9

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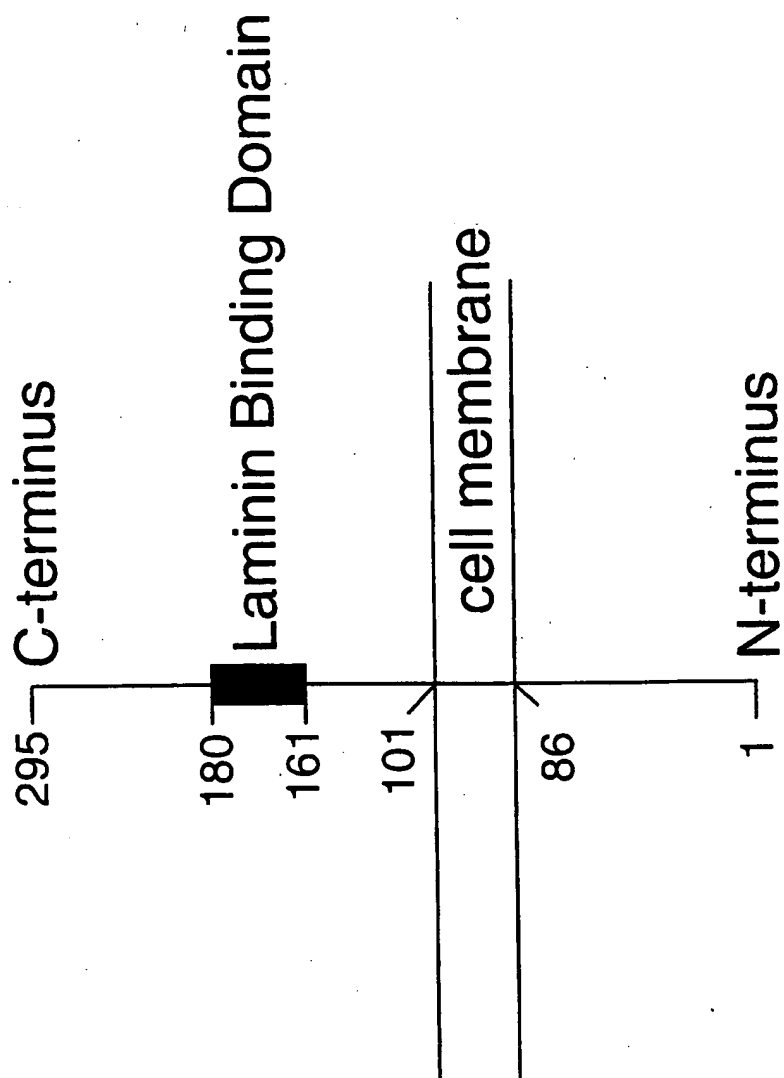


FIGURE 10

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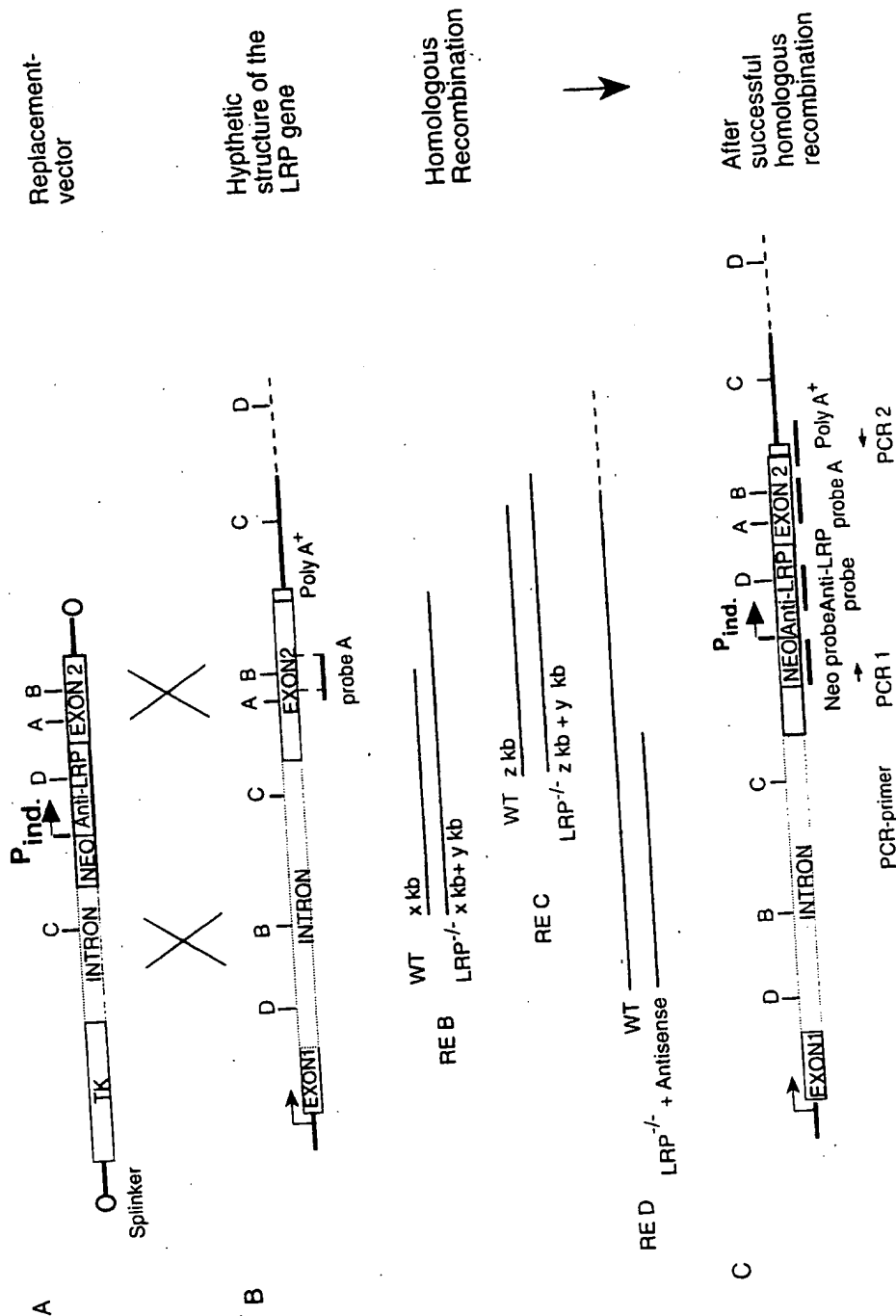


FIGURE 11

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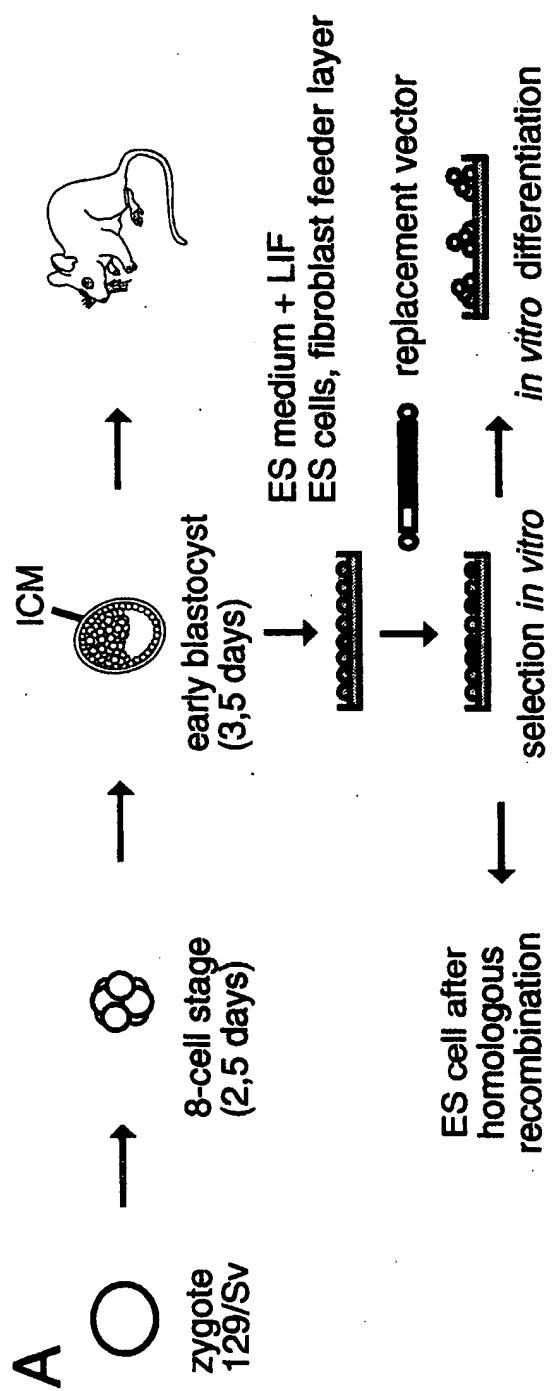


FIGURE 12A

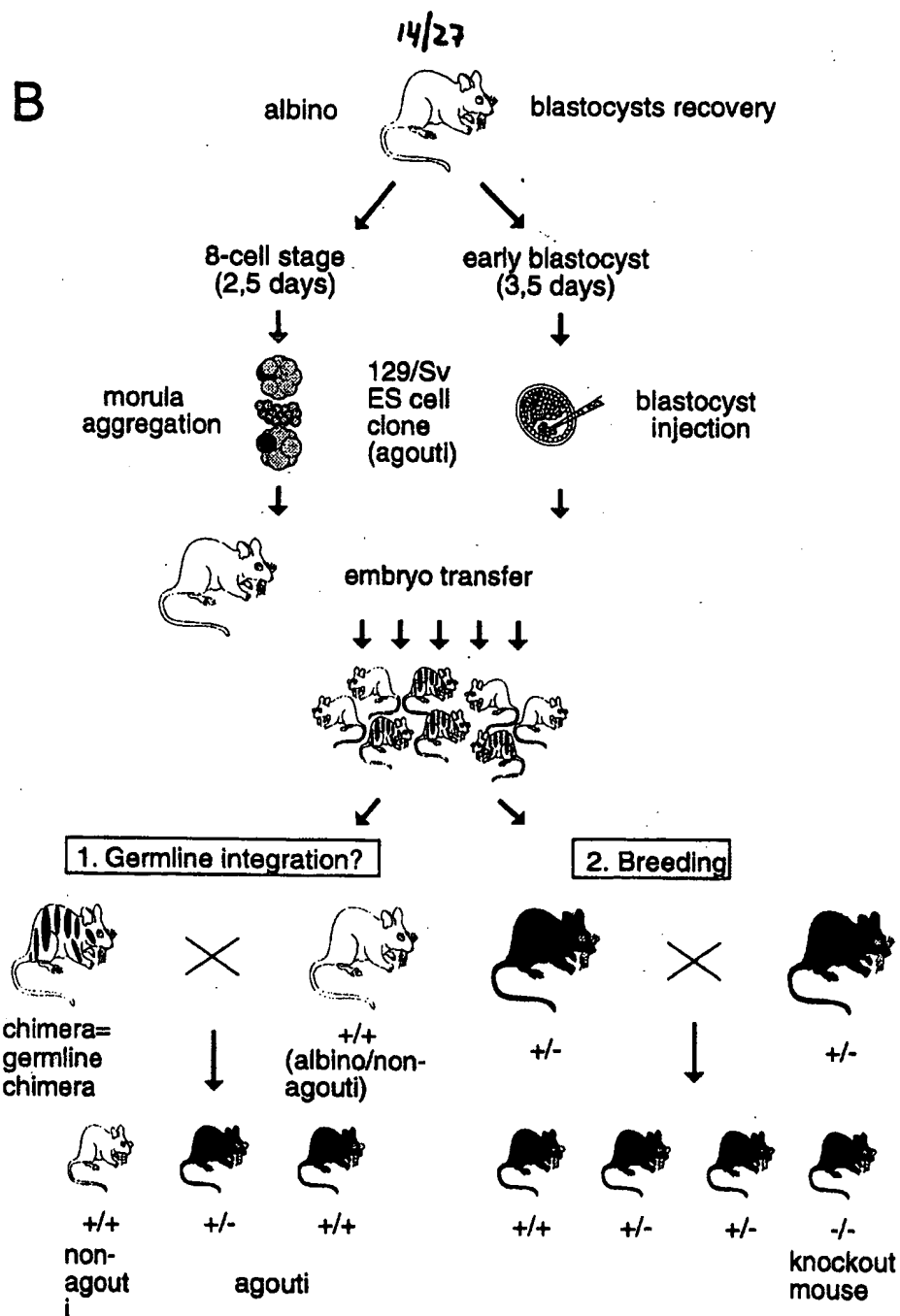


FIGURE 12B

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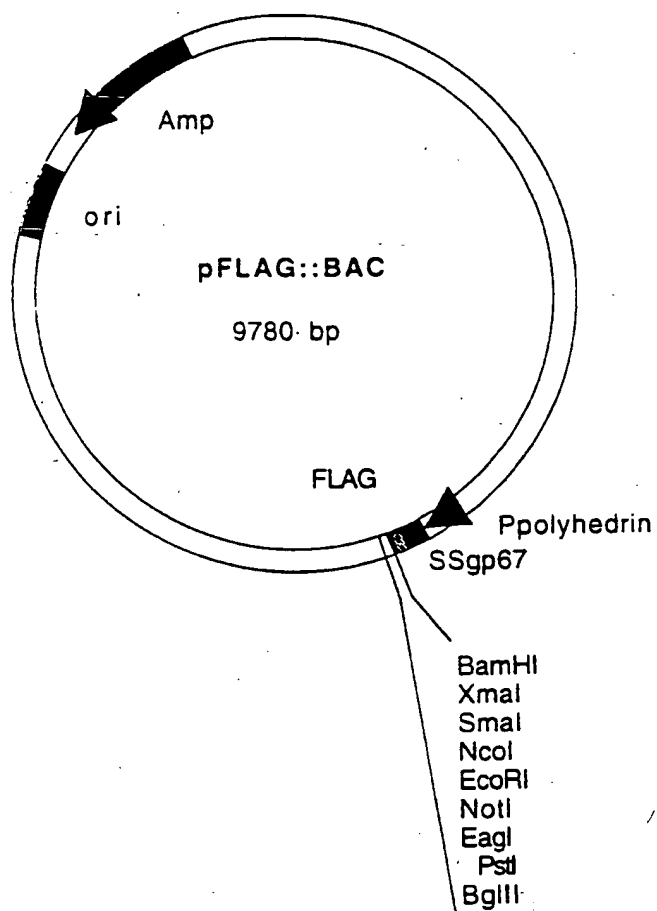


FIGURE 13

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Restriction Sites for pFlagBac

FIGURE 14

page 1

Length of pFlagBac(circular): 9780 bp;

Simple Restriction from: 1 to: 9780; Die, 15. Sep 1998 14:15 Uhr

```

AAGCTTTACT CGTAAAGCGA GTTGAAGGAT CATATTTAGT TCGGTTTATG AGATAAGATT GAAAGCACGT
 10          20          30          40          50          60          70

GTAAAATGTT TCCCGCGCGT TGGCACAAC TTTTACAATG CGGCCAAGTT ATAAAAGATT CTAATCTGAT
 80          90         100         110         120         130         140

ATGTTTTTAAA ACACCTTTGC GGCCCGAGTT GTTTGCGTAC GTGACTAGCG AAGAAGATGT GTGGACCGCA
150         160         170         180         190         200         210

GAACAGATAG TAAAACAAAA CCCTAGTATT GGAGCAATAA TCGATTTAAC CAACACGTCT AAATATTATG
220         230         240         250         260         270         280

ATGGTGTGCA TTTTGTGCGG GCGGGCCTGT TATACAAAAA AATTCAAGTA CCTGGCCAGA CTTTGGCCGC
290         300         310         320         330         340         350

TGAAAGCATA GTTCAAGAAT TTATTGACAC GGTAAAAGAA TTTACAGAAA AGTGTCCCGG CATGTTGGTG
360         370         380         390         400         410         420

GGCGTGCACT GCACACACGG TATTAATCGC ACCGGTTACA TGGTGTGCAG ATATTTAATG CACACCCTGG
430         440         450         460         470         480         490

GTATTGCGCC GCAGGAAGCC ATAGATAGAT TCGAAAAAGC CAGAGGTCAC AAAATTGAAA GACAAAAATTA
500         510         520         530         540         550         560

CGTTCAAGAT TTATTAATTT AATTAATATT ATTTGCATTC TTTAACAAT ACTTTATCCT ATTTTCAAAT
570         580         590         600         610         620         630

TGTGCGCTT CTTCCAGCGA ACCAAACTA TGCTTCGCTT GCTCCGTTTA GCTTGTAGCC GATCAGTGGC
640         650         660         670         680         690         700

GTTGTTCCAA TCGACGGTAG GATTAGCCCG GATATTCTCC ACCACAATGT TGGCAACGTT GATGTTACGT
710         720         730         740         750         760         770

TTATGCTTTT GGTTTTCCAC GTACGCTTTT TGGCCGGTAA TAGCCGTAAA CGTAGTGCCG TCGCGCGTCA
780         790         800         810         820         830         840

                                >> Sac II
                                >> Sst II
CGCACAAACAC CGGATGTTTG CGCTTGTCGG CGGGGTATTG AACC CGCGCA TCCGACAAAT CCACCACTTT
850         860         870         880         890         900         910

                                >> Bst EII
GGCAACTAAA TCGGTGACCT GCGCGTCTTT TTTCTGCATT ATTTCTGCTT TCTTTTGCAT GGTTTCCTGG
920         930         940         950         960         970         980

AAGCCGGTGT ACATGCGGTT TAGATCAGTC ATGACGCGCG TGACCTGCAA ATCTTTGGCC TCGATCTGCT
990         1000        1010        1020        1030        1040        1050

TGTCTTGTAT GGCAACGATG CGTTCAATAA ACTCTTGTIT TTTAACAAGT TCCTCGGTTT TTTGCGCCAC
1060        1070        1080        1090        1100        1110        1120

CACCGCTTGC AGCGCGTTTG TGTGCTCGGT GAATGTCGCA ATCAGCTTAG TCACCAACTG TTTGCTCTCC
1130        1140        1150        1160        1170        1180        1190

TCCTCCCGTT GTTTGATCGC GGGATCGTAC TTGCCGGTGC AGAGCACTTG AGGAATTACT TCTTCTAAAA
1200        1210        1220        1230        1240        1250        1260

GCCATTCCTT TAATTCATAT GCGTAAGGCA ATTTGGACTT CATAATCAGC TGAATCACGC CGGATTTAGT
1270        1280        1290        1300        1310        1320        1330

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Restriction Sites for pFlagBac

FIGURE 14 cont.'d page 2

Ban II >>  
Bvu I >>

AATGAGCACT GTATGCGGCT GCAAATACAG CGGGTCGCCC CTTTTCACGA CGCTGTTAGA GGTAGGGCCC  
1340 1350 1360 1370 1380 1390 1400

CCATTTTGA TGGTCTGCTC AAATAACGAT TTGTATTTAT TGTCTACATG AACACGTATA GCTTTATCAC  
1410 1420 1430 1440 1450 1460 1470

AAACTGTATA TTTTAACTG TTAGCGACGT CTTGGCCAC GAACCGGACC TGTGGTCCG GCTCTAGCAC  
1480 1490 1500 1510 1520 1530 1540

GTACCGCAGG TTGAACGTAT CTTCTCCAAA TTAAATTCT CCAATTTTAA CGCGAGCCAT TTTGATACAC  
1550 1560 1570 1580 1590 1600 1610

GTGTGTCGAT TTGCAACAA CTATTGTTTT TTAACGCAA CTAACTTAT TGTGGTAAGC AATAATTAA  
1620 1630 1640 1650 1660 1670 1680

TATGGGGGAA CATGCGCCGC TACAACACTC GTCGTTATGA ACGCAGACGG CGCCGGTCTC GGCGCAAGCG  
1690 1700 1710 1720 1730 1740 1750

GCTAAACGT GTTGC GCGTT CAACGCGCA AACATCGCAA AAGCCAATAG TACAGTTTTG ATTTGCATAT  
1760 1770 1780 1790 1800 1810 1820

TAACGGCGAT TTTTAAATT ATCTTATTTA ATAAATAGTT ATGACGCCTA CAACTCCCCG CCCGCGTTGA  
1830 1840 1850 1860 1870 1880 1890

>< Pae R7I  
>< Xho I

CTCGCTGCAC CTCGAGCAGT TCGTTGACGC CTTCTCCGT GTGGCCGAAC ACGTCGAGCG GGTGGTCCGAT  
1900 1910 1920 1930 1940 1950 1960

GACCAGCGGC GTGCCGCAG CGACGCACAA GTATCTGTAC ACCGAATGAT CGTCGGGCGA AGGCACGTGC  
1970 1980 1990 2000 2010 2020 2030

GCCTCCAAGT GGCAATATTG GCAAAATCGA AAATATATAC AGTTGGGTTG TTTGCGCATA TCTATCGTGG  
2040 2050 2060 2070 2080 2090 2100

>< Sph I

CGTTGGGCAT GTACGTCCGA ACGTTGATTT GCATGCAAGC CGAAATTAA TCATTGCGAT TAGTGCGATT  
2110 2120 2130 2140 2150 2160 2170

>< Bcl I

AAAACGTTGT ACATCCTCGC TTITAATCAT GCCGTCGATT AAATCGCGCA ATCGAGTCAA GTGATCAAAG  
2180 2190 2200 2210 2220 2230 2240

TGTGGAATAA TGTTTTCTTT GTATTCCTCGA GTCAAGCGCA GCGCGTATTT TAACAAACTA GCCATCTTGT  
2250 2260 2270 2280 2290 2300 2310

AAGTTAGTTT CATTTAATGC AACTTTATCC AATAATATAT TATGTATCGC ACGTCAAGAA TTAACAATGC  
2320 2330 2340 2350 2360 2370 2380

GCCCGTTGTC GCATCTCAAC ACGACTATGA TAGAGATCAA ATAAAGCGCG AATTAAATAG CTTGCGACGC  
2390 2400 2410 2420 2430 2440 2450

AACGTGCACG ATCTGTGCAC GCGTTCCGGC ACGAGCTTTG ATTGTAATAA GTTTTACGA AGCGATGACA  
2460 2470 2480 2490 2500 2510 2520

TGACCCCCGT AGTGACAACG ATCAGCCCCA AAAGAACTGC CGACTACAAA ATTACCGAGT ATGTCGGTGA  
2530 2540 2550 2560 2570 2580 2590

CGTTAAAACT ATTAAGCCAT CCAATCGACC GTTAGTCGAA TCAGGACCGC TGGTGCGAGA AGCCGCGAAG  
2600 2610 2620 2630 2640 2650 2660

TATGGCGAAT GCATCGTATA ACGTGTGGAG TCCGCTCATT AGAGCGTCAT GTTTAGACAA GAAAGCTACA  
2670 2680 2690 2700 2710 2720 2730

## 18/27 Restriction Sites for pFlagBac FIGURE 14 cont.'d

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TATTTAATG	ATCCCGATGA	TTTTATTGAT	AAATTGACCC	TAACTCCATA	CACGGTATTC	TACAATGGCG
2740	2750	2760	2770	2780	2790	2800
GGGTTTGGT	CAAATTTCC	GGACTGCGAT	TGTACATGCT	GTTAACGGCT	CCGCCCCACTA	TTAATGAAAT
2810	2820	2830	2840	2850	2860	2870
TAAAAATTC	AATTTTAAAA	AACGCAGCAA	GAGAAACATT	TGTATGAAAG	AATGCGTAGA	AGGAAAGAAA
2880	2890	2900	2910	2920	2930	2940
AATGTCGTCG	ACATGCTGAA	CAACAAGATT	AATATGCCTC	CGTGTATAAA	AAAAATATTG	AACGATTTGA
2950	2960	2970	2980	2990	3000	3010
AAGAAAACAA	TGTACCGCGC	GGCGGTATGT	ACAGGAAGAG	GTTTATACTA	AACGTGTACA	TTGCAAACGT
3020	3030	3040	3050	3060	3070	3080
GGTTTCGTGT	GCCAAGTGTG	AAAACCGATG	TTTAATCAAG	GCTCTGACGC	ATTTCTACAA	CCACGACTCC
3090	3100	3110	3120	3130	3140	3150
AAGTGTGTGG	GTGAAGTCAT	GCATCTTTTA	ATCAAATCCC	AAGATGTGTA	TAAACCACCA	AACGTCCAAA
3160	3170	3180	3190	3200	3210	3220
AAATGAAAAC	TGTCGACAAG	CTCTGTCCGT	TTGCTGGCAA	CTGCAAGGGT	CTCAATCCTA	TTTGTAAATTA
3230	3240	3250	3260	3270	3280	3290
TTGAATAATA	AAACAATTAT	AAATGCTAAA	TTTGTTTTTT	ATTAACGATA	CAAACCAAAC	GCAACAAGAA
3300	3310	3320	3330	3340	3350	3360
CATTGTAGT	ATTATCTATA	ATTGAAAACG	CGTAGTTATA	ATCGCTGAGG	TAATATTTAA	AATCATTTTC
3370	3380	3390	3400	3410	3420	3430
AAATGATTCA	CAGTTAATTT	GCGACAATAT	AATTTTATTT	TCACATAAAC	TAGACGCCTT	GTCGTCTTCT
3440	3450	3460	3470	3480	3490	3500
TCTTCGTATT	CCTTCTCTTT	TTCAATTTTC	TCCTCATAAA	AATTAACATA	GTTATTATCG	TATCCATATA
3510	3520	3530	3540	3550	3560	3570
TGTATCTATC	GTATAGAGTA	AATTTTTTGT	TGTCATAAAT	ATATATGTCT	TTTTTAATGG	GGTGTATAGT
3580	3590	3600	3610	3620	3630	3640
ACCGCTGCGC	ATAGTTTTTC	TGTAATTTAC	AACAGTGCTA	TTTTCTGGTA	GTTCTTCGGA	GTGTGTTGCT
3650	3660	3670	3680	3690	3700	3710
>< Nae I						
> < Ngo M I						
TTAATTATTA	AATTTATATA	ATCAATGAAT	TTGGGATCGT	CGGTTTGTGA	CAATATGTTG	CCGGCATAGT
3720	3730	3740	3750	3760	3770	3780
ACGCAGCTTC	TTCTAGTTCA	ATTACACCAT	TTTTTAGCAG	CACCGGATTA	ACATAACTTT	CCAAAATGTT
3790	3800	3810	3820	3830	3840	3850
GTACGAACCG	TTAAACAAAA	ACAGTTCACC	TCCCTTTTCT	ATACTATTGT	CTGCGAGCAG	TTGTTTGTG
3860	3870	3880	3890	3900	3910	3920
TTAAAAATAA	CAGCCATTGT	AATGAGACGC	ACAAACTAAT	ATCACAAACT	GGAAATGTCT	ATCAATATAT
3930	3940	3950	3960	3970	3980	3990
> < Eco RV						
AGTTGCTGAT	ATCATGGAGA	TAATTAAAT	GATAACCATC	TCGCAAATAA	ATAAGTATTT	TACTGTTTTT
4000	4010	4020	4030	4040	4050	4060
GTAACAGTTT	TGTAATAAAA	AAACCTATAA	ATATTCCGGA	TTATTCATAC	CGTCCCACCA	TCGGGCGCGG
4070	4080	4090	4100	4110	4120	4130
> < Spe I						

## Restriction Sites for pFlagBac

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FIGURE 14 cont.'d

page 4

ATCTATGCTA CTAGTAAATC AGTCACACCA AGGCTTCAAT AAGGAACACA CAAGCAAGAT GGTAAGCGCT  
 4140 4150 4160 4170 4180 4190 4200  
 ATTTGTTTTAT ATGTGCTTTT GGCGGCGGCG GCGCATTTCTG CCTTTGCGGA CTACAAGGAC GACGATGACA  
 4210 4220 4230 4240 4250 4260 4270  
 >< AlI I  
 >< Bam HI >< Eco RI >< Eag I >< Bgl II  
 >< Nco I >< Not I >< Pst I >< Ppu MI  
 >< Sma I  
 >< Xcy I  
 >< Xma I >< Xma III> < Xor I  
 AGGGATCCCG GGCCATGGGA ATTCCGGAGC GGCCGCTGCA GATCTGATCC TTTCCTGGGA CCCGGAAGA  
 4280 4290 4300 4310 4320 4330 4340  
 ACCAAAACT CACTCTCTTC AAGGAAATCC GTAATGTTAA ACCCGACACG ATGAAGCTTG TCGTTGGATG  
 4350 4360 4370 4380 4390 4400 4410  
 GAAAGGAAAA GAGTTCTACA GGGAAACTTG GACCCGCTTC ATGGAAGACA GCTTCCCCAT TGTTAACGAC  
 4420 4430 4440 4450 4460 4470 4480  
 CAAGAAGTGA TGGATGTTTT CCTTGTGTGC AACATGCGTC CCACTAGACC CAACCGTTGT TACAAATTCC  
 4490 4500 4510 4520 4530 4540 4550  
 TGGCCCAACA CGCTCTCGGT TGCGACCCCG ACTATGTACC TCATGACGTG ATTAGGATCG TCGAGCCTTC  
 4560 4570 4580 4590 4600 4610 4620  
 ATGGGTGGGC AGCAACAACG AGTACCGCAT CAGCCTGGCT AAGAAGGGCG GCGGCTGCCC AATAATGAAC  
 4630 4640 4650 4660 4670 4680 4690  
 CTTCACTCTG AGTACACCAA CTCGTTTCGAA CAGTTCATCG ATCGTGTGAT CTGGGAGAAC TTCTACAAGC  
 4700 4710 4720 4730 4740 4750 4760  
 >< Asp 718  
 >< Kpn I  
 CCATCGTTTA CATCGGTACC GACTCTGCTG AAGAGGAGGA AATTCTCCTT GAAGTTTCCC TGGTGTTCAA  
 4770 4780 4790 4800 4810 4820 4830  
 AGTAAAGGAG TTTCACCCAG ACGCACCTCT GTTCACTGGT CCGGCGTATT AAAACACGAT ACATTGTTAT  
 4840 4850 4860 4870 4880 4890 4900  
 >< Sna BI  
 TAGTACATTT ATTAAGCGCT AGATTCTGTG CGTTGTGTGAT TTACAGACAA TTGTGTGACG TATTTTAAATA  
 4910 4920 4930 4940 4950 4960 4970  
 ATTCATTAAA TTTATAATCT TTAGGGTGGT ATGTTAGAGC GAAAATCAAA TGATTTTCAG CGTCTTTATA  
 4980 4990 5000 5010 5020 5030 5040  
 TCTGAATTTA AATATTAAAT CCTCAATAGA TTTGTAAAAT AGGTTTCGAT TAGTTTCAAA CAAGGGTGT  
 5050 5060 5070 5080 5090 5100 5110  
 TTTTCCGAAC CGATGGCTGG ACTATCTAAT GGATTTTCGC TCAACGCCAC AAAACTTGCC AAATCTTGTA  
 5120 5130 5140 5150 5160 5170 5180  
 GCAGCAATCT AGCTTTGTGCG ATATTCTGTT GTGTTTGTGT TTGTAATAAA GGTTCGACGT CGTTCAAAAT  
 5190 5200 5210 5220 5230 5240 5250  
 ATTATCGCGT TTTGTATTTT TTTCACTACT GTCGTTAGTG TACAATTGAC TCGACGTAAA CACGTTAAAT  
 5260 5270 5280 5290 5300 5310 5320  
 AAAGCTTGGG CATATTTAAC ATCGGGCGTG TTAGCTTTAT TAGGCCGATT ATCGTCGTCG TCCCAACCCCT  
 5330 5340 5350 5360 5370 5380 5390  
 CGTCGTTAGA AGTTGCTTCC GAAGACGATT TTGCCATAGC CACACGACGC CTATTAATTG TGTCGGCTAA  
 5400 5410 5420 5430 5440 5450 5460

## Restriction Sites for pFlagBac

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FIGURE 14 cont.'d page 5

CACGTCCGCG	ATCAAATTTG	TAGTTGAGCT	TTTTGGAATT	ATTTCTGATT	GCGGGCGTTT	TTGGGCGGGT
5470	5480	5490	5500	5510	5520	5530
TTCAATCTAA	CTGTGCCCGA	TTTTAATTCA	GACAACACGT	TAGAAAGCGA	TGGTGCAGGC	GGTGGTAACA
5540	5550	5560	5570	5580	5590	5600
TTTCAGACGG	CAAATCTACT	AATGGCGGCG	GTGGTGGAGC	TGATGATAAA	TCTACCATCG	GTGGAGGCGC
5610	5620	5630	5640	5650	5660	5670
AGGCGGGGCT	GGCGGCGGAG	GCGGAGGCGG	AGGTGGTGGC	GGTGATGCAG	ACGGCGGTTT	AGGCTCAAAT
5680	5690	5700	5710	5720	5730	5740
GTCTCTTTAG	GCAACACAGT	CGGCACCTCA	ACTATTGTAC	TGGTTTCGGG	CGCCGTMTTT	GGTTTGACCG
5750	5760	5770	5780	5790	5800	5810
GTCTGAGACG	AGTGGCATTT	TTTTCGTTTC	TAATAGCTTC	CAACAATTGT	TGTCTGTCGT	CTAAAGGTGC
5820	5830	5840	5850	5860	5870	5880
AGCGGGTTGA	GGTTCCGTCG	GCAATGGTGG	AGCGGGCGGC	AATTCAGACA	TCGATGGTGG	TGGTGGTGGT
5890	5900	5910	5920	5930	5940	5950
GGAGGCGCTG	GAATGTTAGG	CACGGGAGAA	GGTGGTGGCG	GCGGTGCCGC	CGGTATAATT	TGTTCTGGTT
5960	5970	5980	5990	6000	6010	6020
>< Sgr A I						
TAGTTTGTTTC	GCGCACGATT	GTGGGCACCG	GCGCAGGCGC	CGCTGGCTGC	ACAACGGAAG	GTCGTCTGCT
6030	6040	6050	6060	6070	6080	6090
TCGAGGCAGC	GCTTGGGGTG	GTGGCAATTC	AATATTATAA	TTGGAATACA	AATCGTAAAA	ATCTGCTATA
6100	6110	6120	6130	6140	6150	6160
AGCATTGTAA	TTTCGCTATC	GTTTACCGTG	CCGATATTTA	ACAACCGCTC	AATGTAAGCA	ATTGTATTGT
6170	6180	6190	6200	6210	6220	6230
AAAGAGATTG	TCTCAAGCTC	CGCACGCCGA	TAACAAGCCT	TTTCATTTTT	ACTACAGCAT	TGTAGTGGCG
6240	6250	6260	6270	6280	6290	6300
AGACACTTCG	CTGTCGTCGA	CGTACATGTA	TGCTTTGTTC	TCAAAAACGT	CGTTGGCAAG	CTTTAAATA
6310	6320	6330	6340	6350	6360	6370
TTTAAAAGAA	CATCTCTGTT	CAGCACCACT	GTGTTGTCTG	AAATGTTGTT	TTTGATAATT	TGCGCTTCCG
6380	6390	6400	6410	6420	6430	6440
CAGTATCGAC	ACGTTCAAAA	AATTGATGCG	CATCAATTTT	GTTGTTCCCTA	TTATTGAATA	AATAAGATTG
6450	6460	6470	6480	6490	6500	6510
TACAGATTCA	TATCTACGAT	TCGTACATGGC	CACCACAAAT	GCTACGCTGC	AAACGCTGGT	ACAATTTTAC
6520	6530	6540	6550	6560	6570	6580
GAAAACTGCA	AAAACGTCAA	AACTCGGTAT	AAAATAATCA	ACGGGCGCTT	TGGCAAAATA	TCTATTTTAT
6590	6600	6610	6620	6630	6640	6650
CGCACAAGCC	CACTAGCAAA	TTGTATTTGC	AGAAAACAAT	TTCGGCGCAC	AATTTTAACG	CTGACGAAAT
6660	6670	6680	6690	6700	6710	6720
AAAAGTTTAC	CAGTTAATGA	GCGACCACCC	AAATTTTATA	AAAATCTATT	TTAATCACGG	TTCCATCAAC
6730	6740	6750	6760	6770	6780	6790
AACCAAGTGA	TCGTGATGGA	CTACATTGAC	TGTCCCGATT	TATTTGAAAC	ACTACAAATT	AAAGGCGAGC
6800	6810	6820	6830	6840	6850	6860
TTTCGTACCA	ACTTGTTAGC	AATATTATTA	GACAGCTGTG	TGAAGCGCTC	AACGATTTCG	ACAAGCACAA
6870	6880	6890	6900	6910	6920	6930

## Restriction Sites for pFlagBac

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FIGURE 14 cont.'d page 6

TTTCATACAC	AACGACATA	AACCTCGAAAA	TGCTTTATAT	TTTGAAGCAC	TTGATCGCGT	GTATGTTTGC
6940	6950	6960	6970	6980	6990	7000
GATTACGGAT	TGTGCAACA	CGAAAACTCA	CTTAGCGTGC	ACGACGGCAC	GTTGGAGTAT	TTTAGTCCGG
7010	7020	7030	7040	7050	7060	7070
AAAAAATTCG	ACACACAAC	ATGCACGTTT	CGTTTGACTG	GTACGCGGCG	TGTTAACATA	CAAGTTGCTA
7080	7090	7100	7110	7120	7130	7140
ACCGGCGGTT	CGTAATCATG	GTCATAGCTG	TTTCCTGTGT	GAAATTGTTA	TCCGCTCACA	ATTCCACACA
7150	7160	7170	7180	7190	7200	7210
ACATACGAGC	CGGAAGCATA	AAGTGTAAG	CCTGGGGTGC	CTAATGAGTG	AGCTAACTCA	CATTAAATTGC
7220	7230	7240	7250	7260	7270	7280
GTTGCGCTCA	CTGCCCCGTT	TCCAGTCGGG	AAACCTGTGC	TGCCAGCTGC	ATTAATGAAT	CGGCCAACGC
7290	7300	7310	7320	7330	7340	7350
GCGGGGAGAG	GCGGTTTGCG	TATTGGGCGC	TCTTCCGCTT	CCTCGCTCAC	TGACTCGCTG	CGCTCGGTGC
7360	7370	7380	7390	7400	7410	7420
TTGCGCTGCG	GCGAGCGGTA	TCAGCTCACT	CAAAGGCGGT	AATACGGTTA	TCCACAGAAT	CAGGGGATAA
7430	7440	7450	7460	7470	7480	7490
CGCAGGAAAG	AACATGTGAG	CAAAAGGCCA	GCAAAAGGCC	AGGAACCGTA	AAAAGGCCGC	GTTGCTGGCG
7500	7510	7520	7530	7540	7550	7560
TTTTTCCATA	GGCTCCGCCC	CCCTGACGAG	CATCACAAAA	ATCGACGCTC	AAGTCAGAGG	TGGCGAAACC
7570	7580	7590	7600	7610	7620	7630
CGACAGGACT	ATAAGATAC	CAGGCGTTTC	CCCCTGGAAG	CTCCCTCGTG	CGCTCTCTTG	TTCCGACCCT
7640	7650	7660	7670	7680	7690	7700
GCCGCTTACC	GGATACCTGT	CCGCTTTTCT	CCCTTCGGGA	AGCGTGGCGC	TTTCTCATAG	CTCACGCTGT
7710	7720	7730	7740	7750	7760	7770
AGGTATCTCA	GTTCCGGTGA	GGTCGTTTCG	TCCAAGCTGG	GCTGTGTGCA	CGAACCCCCC	GTTTCAGCCG
7780	7790	7800	7810	7820	7830	7840
ACCGCTGCGC	CTTATCCGGT	AACTATCGTC	TTGAGTCCAA	CCCGGTAAGA	CACGACTTAT	CGCCACTGGC
7850	7860	7870	7880	7890	7900	7910
>< Alw NI						
AGCAGCCACT	GGTAACAGGA	TTAGCAGAGC	GAGGTATGTA	GGCGGTGCTA	CAGAGTTCTT	GAAGTGGTGG
7920	7930	7940	7950	7960	7970	7980
CCTAACTACG	GCTACACTAG	AAGGACAGTA	TTTGGTATCT	GCGCTCTGCT	GAAGCCAGTT	ACCTTCGGAA
7990	8000	8010	8020	8030	8040	8050
AAAGAGTTGG	TAGCTCTTGA	TCCGGCAAAC	AAACCACCGC	TGGTAGCGGT	GGTTTTTTTG	TTTGCAAGCA
8060	8070	8080	8090	8100	8110	8120
GCAGATTACG	CGCAGAAAA	AAGGATCTCA	AGAAGATCCT	TTGATCTTTT	CTACGGGGTC	TGACGCTCAG
8130	8140	8150	8160	8170	8180	8190
TGGAACGAAA	ACTCACGTTA	AGGGATTTTG	GTCATGAGAT	TATCAAAAAG	GATCTTCACC	TAGATCCTTT
8200	8210	8220	8230	8240	8250	8260
TAAATTAAAA	ATGAAGTTT	AAATCAATCT	AAAGTATATA	TGAGTAAACT	TGGTCTGACA	GTTACCAATG
8270	8280	8290	8300	8310	8320	8330
CTTAATCAGT	GAGGCACCTA	TCTCAGCGAT	CTGTCTATTT	CGTTCATCCA	TAGTTGCCTG	ACTCCCCGTC
8340	8350	8360	8370	8380	8390	8400
GTGTAGATAA	CTACGATACG	GGAGGGCTTA	CCATCTGGCC	CCAGTGCTGC	AATGATACCG	CGAGACCCAC

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FIGURE 14 cont.'d

Restriction Sites for pFlagBac

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8410	8420	8430	8440	8450	8460	8470
GCTCACC GGC	TCCAGATT TTA	TCAGCAATAA	ACCAGCCAGC	CGGAAGGGCC	GAGCGCAGAA	GTGGTCCTGC
8480	8490	8500	8510	8520	8530	8540
AACTTTATCC	GCCTCCATCC	AGTCTATTAA	TTGTTGCCGG	GAAGCTAGAG	TAAGTAGTTC	GCCAGTTAAT
8550	8560	8570	8580	8590	8600	8610
AGTTTGGCGA	ACGTTGTTGC	CATTGCTACA	GGCATCGTGG	TGTCACGCTC	GTCGTTTGGT	ATGGCTTCAT
8620	8630	8640	8650	8660	8670	8680
TCAGCTCCGG	TTCCCAACGA	TCAAGGCGAG	TTACATGATC	CCCCATGTTG	TGCAAAAAAG	CGGTTAGCTC
8690	8700	8710	8720	8730	8740	8750
CTTCGGTCCT	CCGATCGTTG	TCAGAAGTAA	GTTGGCCGCA	GTGTTATCAC	TCATGGTTAT	GGCAGCACTG
8760	8770	8780	8790	8800	8810	8820
CATAATTCTC	TTACTGTCAT	GCCATCCGTA	AGATGCTTTT	CTGTGACTGG	>< Sca I	
8830	8840	8850	8860	8870	8880	8890
TCTGAGAATA	GTGTATGCGG	CGACCGAGTT	GCTCTTGCCC	GGCGTCAATA	CGGGATAATA	CCGCGCCACA
8900	8910	8920	8930	8940	8950	8960
TAGCAGAACT	TTAAAAGTGC	TCATCATTGG	AAAACGTTCT	TCGGGGCGAA	AACTCTCAAG	GATCTTACCG
8970	8980	8990	9000	9010	9020	9030
CTGTTGAGAT	CCAGTTCGAT	GTAACCCACT	CGTGCACCCA	ACTGATCTTC	AGCATCTTTT	ACTTTCACCA
9040	9050	9060	9070	9080	9090	9100
GCGTTTCTGG	GTGAGCAAAA	ACAGGAAGGC	AAAATGCCGC	AAAAAAGGGA	ATAAGGGCGA	CACGGAAATG
9110	9120	9130	9140	9150	9160	9170
TTGAATACTC	ATACTCTTCC	TTTTTCAATA	TTATTGAAGC	ATTATACAGG	GTTATTGTCT	CATGAGCGGA
9180	9190	9200	9210	9220	9230	9240
TACATATTTG	AATGTATTTA	GAAAAATAAA	CAAATAGGGG	TTCCGCGCAC	ATTTCCCCGA	AAAGTGCCAC
9250	9260	9270	9280	9290	9300	9310
CTGACGTCTA	AGAAACCATT	ATTATCATGA	CATTAACTTA	TAAAAATAGG	CGTATCACGA	GGCCCTTTTCG
9320	9330	9340	9350	9360	9370	9380
TCTCGCGCGT	TTCGGTGATG	ACGGTGAAAA	CCTCTGACAC	ATGCAGCTCC	CGGAGACGGT	CACAGCTTGT
9390	9400	9410	9420	9430	9440	9450
CTGTAAGCGG	ATGCCGGGAG	CAGACAAGCC	CGTCAGGGCG	CGTCAGCGGG	TGTTGGCGGG	TGTCGGGGCT
9460	9470	9480	9490	9500	9510	9520
GGCTTAACTA	TGCGGCATCA	GAGCAGATTG	TACTGAGAGT	GCACCATATG	CGGTGTGAAA	TACCGCACAG
9530	9540	9550	9560	9570	9580	9590
ATGCGTAAGG	AGAAAATACC	GCATCAGGCG	CCATTGCGCA	TTCAGGCTGC	GCAACTGTTG	GGAAGGGCGA
9600	9610	9620	9630	9640	9650	9660
TCGGTGCGGG	CCTCTTCGCT	ATTACGCCAG	CTGGCGAAAG	GGGGATGTGC	TGCAAGGCGA	TTAAGTTGGG
9670	9680	9690	9700	9710	9720	9730
TAACGCCAGG	GTTTTCCCAG	TCACGACGTT	GTAAAACGAC	GGCCAGTGCC	>< Nde I	
9740	9750	9760	9770	9780		

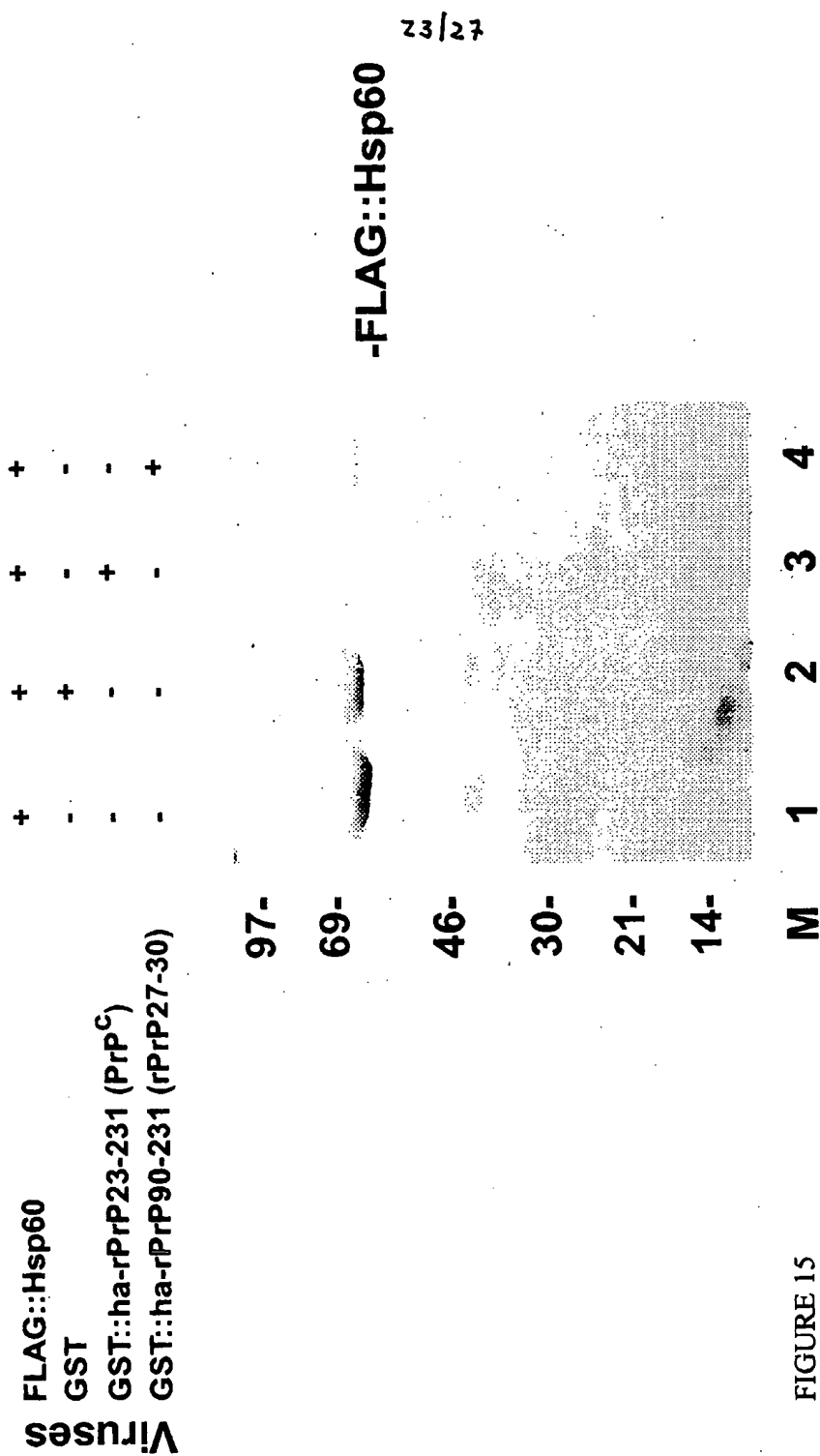


FIGURE 15

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# LRP levels in organs of Scrapie/BSE infected mice analyzed by Western Blotting

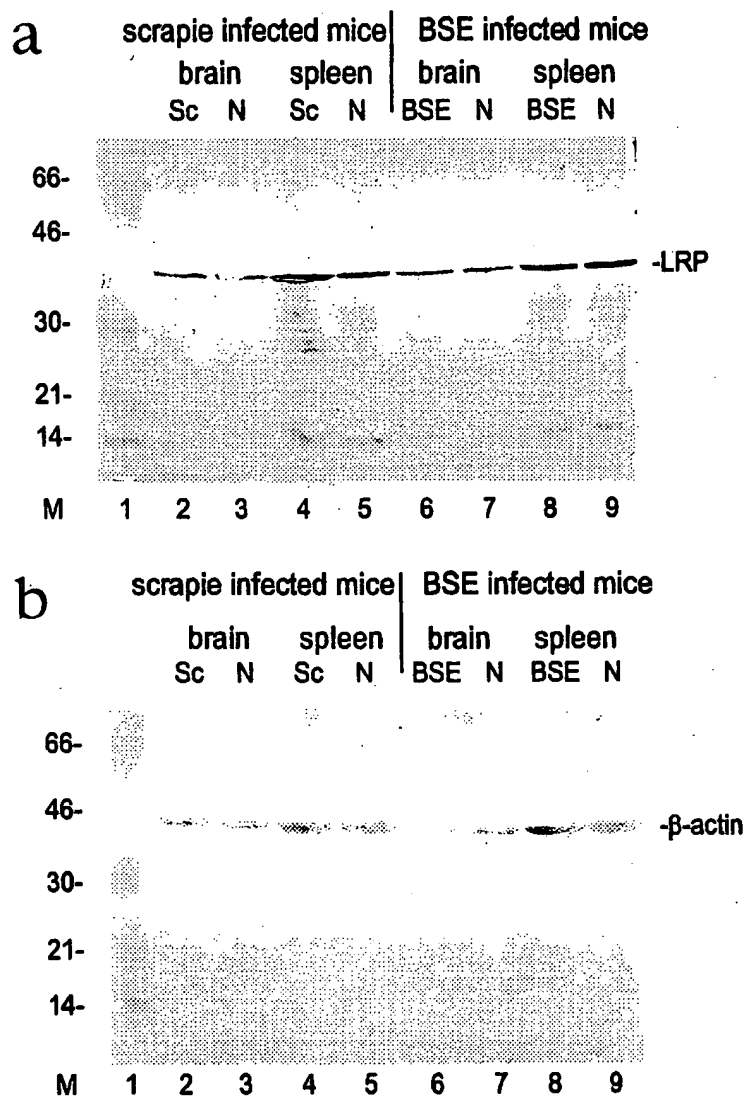


FIGURE 16



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### LRP levels in organs of Scrapie infected hamsters analyzed by Western Blotting

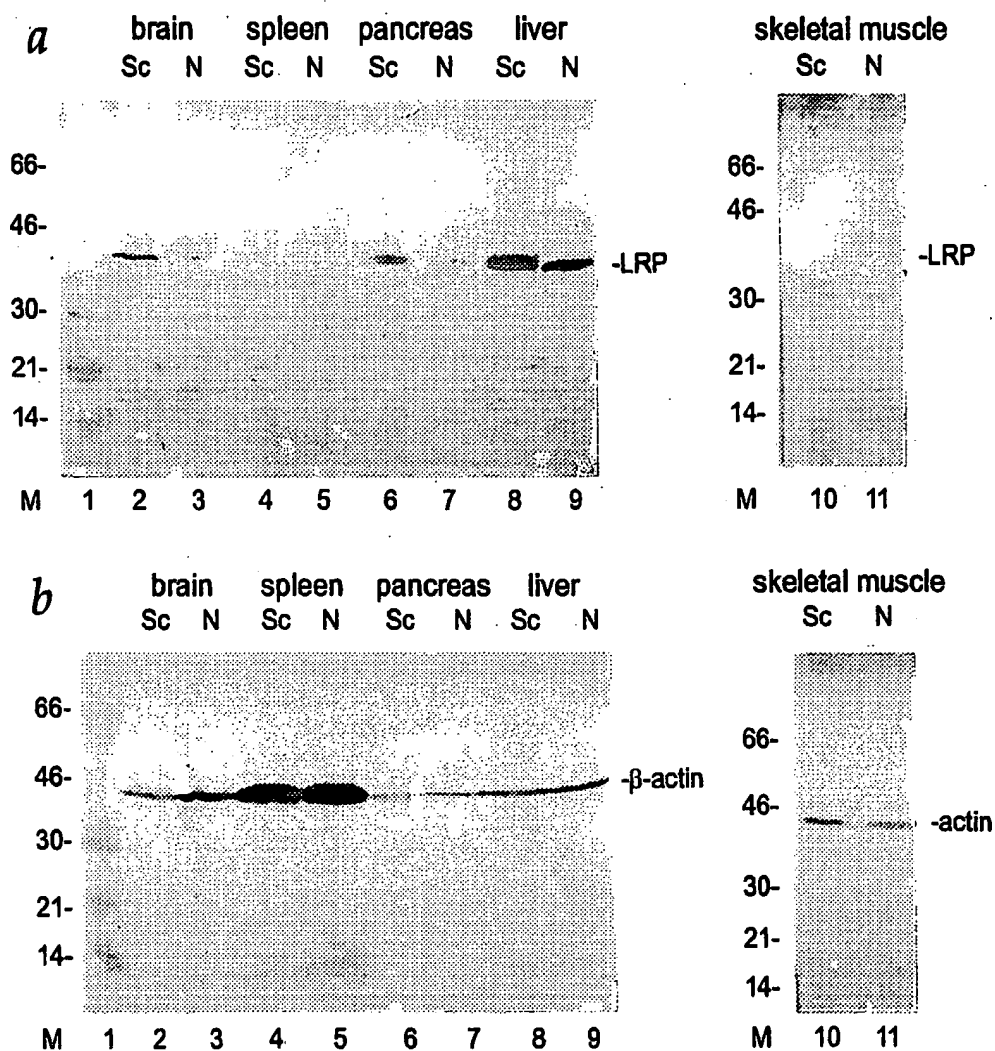


FIGURE 17

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N<sub>2</sub>a cells incubated with a LRP specific antibody

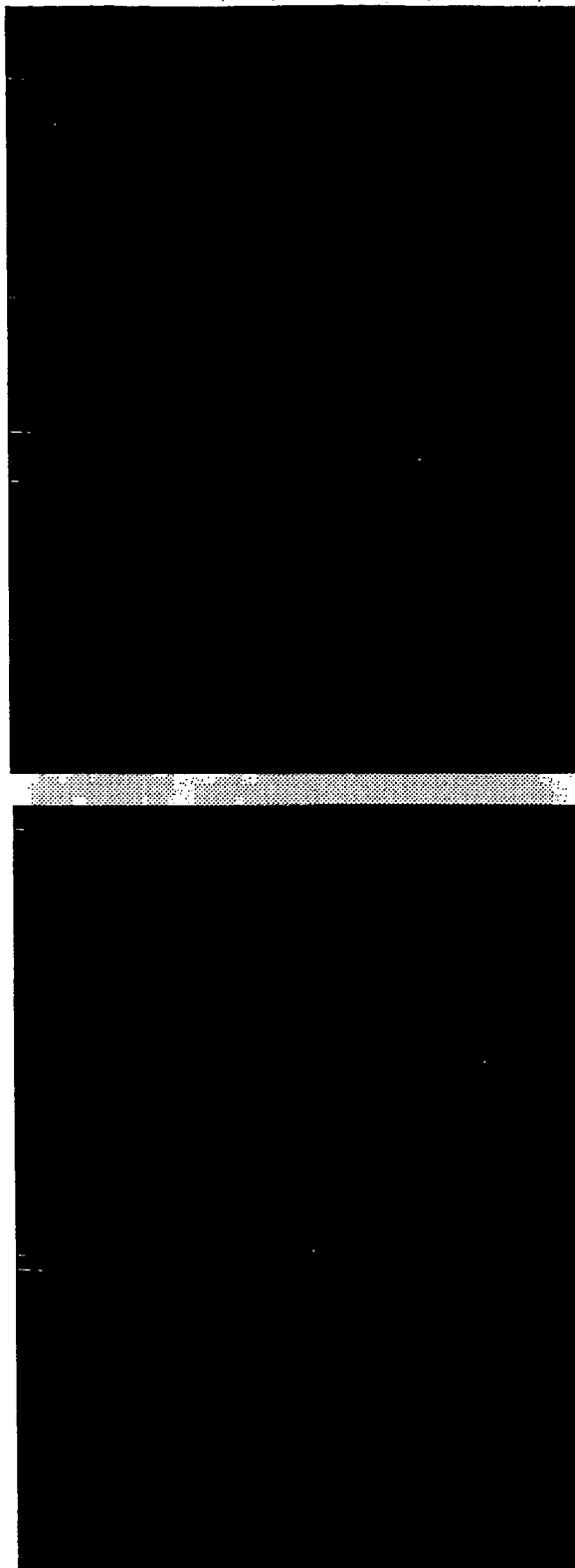


FIGURE 18

# Recombinant bovine PrP<sup>C</sup> interacts on N2a cells with the 37 kDa laminin receptor precursor

N2a + bovPrP<sup>C</sup>  
+ LRP Antibody

N2a + bovPrP<sup>C</sup>



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FIGURE 19